GREENHOUSES
THEIR CONSTRUCTION AND EQUIPMENT

W. J. WRIGHT

Conservatories, New York Botanical Gardens, Bronx Park
(Courtesy Lord and Burnham Co.)

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By

W. J. WRIGHT,

Director, New York State School of Agriculture at Alfred University. Formerly Assistant Professor of Horticulture at the Pennsylvania State College

ILLUSTRATED

NEW YORK
ORANGE JUDD COMPANY
LONDON
KEGAN PAUL, TRENCH, TRÜBNER & CO., Limited
1917

Entered at Stationers' Hall
London, England

Printed in U. S. A.

TO MY FATHER

IN WHOSE FLUE-HEATED, SHED ROOF PROPAGATING

HOUSE I FIRST LEARNED TO LOVE THE

SMELL OF THE SOIL

PREFACE

In 1912 the author was asked to present a paper before the National Vegetable Growers' Association on the construction and equipment of greenhouses, with special reference to the vegetable forcing industry. Much of the data given in this paper had been hitherto unavailable and was based on an extensive personal survey of greenhouse owners and operators, supplemented by personal experience and observation. So great has been the demand for this data that at the request of the Orange Judd Company, the author has undertaken to incorporate it in book form. The present volume attempts a more thorough discussion of the subject than could be given in a single paper. It is based upon a series of lectures given before the author's classes.

This is the second book, dealing exclusively with this subject, which has been published in the United States. The former, written by Prof. L. R. Taft and published by

the Orange Judd Company in 1893, has been the standard and only work devoted entirely to greenhouse construction as adapted to American conditions. To this and to Professor Taft the author of the present volume is deeply indebted. It is not intended that this second book shall supersede the former but that it shall supplement it and emphasize present-day features. Probably in no line of horticulture has so great progress been made in the past quarter of a century as in floriculture and vegetable forcing. The development of the forcing house has been no less rapid.

No attempt has been made to discuss the question of greenhouse construction from the standpoint of the manufacturer, although due credit must be given to the energy and ingenuity which he has displayed in meeting the rapidly changing conditions and in the excellence of present-day construction. It is probably not too much to say, that the development of the flower and vegetable forcing industry has been largely dependent upon the improvement which has been made in the manufacture of greenhouse material and equipment.

The real purpose of the book is to pre-

sent to the reader such information concerning the location, adaptation, general construction and equipment of greenhouses as will enable him to decide upon the type of house best adapted to his special needs; to supervise or assist if need be in its construction or erection; to arrive at some conclusion as to the equipment most likely to render the service required, and the probable cost. A special effort has been made to make the volume of service to the present owner of a greenhouse and to those who may contemplate building, whether it be a small private house or a large commercial range. The arrangement of topics is made with reference to a pedagogical system which it is hoped will be of service to the teacher and student.

It is practically impossible to give individual credit for all the sources drawn upon in the preparation of this volume. Special mention should be made, however, of the assistance given by the manufacturers of greenhouse building material and for the many excellent illustrations which they have furnished. When practicable, the source of these illustrations is given. Free use has also been made of bulletins of the various

Experiment Stations and of the United States Department of Agriculture.

The book is offered with a full consciousness of its shortcomings, but with the hope that it may be of some definite service and that it may serve as a focusing point for criticisms and suggestions, out of which may be born a fuller knowledge through the experience and observation of its readers.

W. J. Wright.

New York State
School of Agriculture, 1917,
Alfred, New York.

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GREENHOUSES

CHAPTER I

A GENERAL SURVEY

It is not the purpose of this book to furnish detailed information concerning the manufacture of greenhouse building material, for the cutting and shaping of the materials is the work of the mill and the factory. Its purpose is rather to present such information concerning the location, adaptation, erection and equipment of greenhouses as will enable the reader to decide upon the type of house best adapted to his special needs; to supervise or assist if need be, in its construction or erection; and to arrive at some conclusion as to the equipment most likely to render the service required.

Greenhouses are the result of an attempt on the part of man to create conditions favorable to the growth of plants in climates or during seasons naturally unfavorable. They must, therefore, protect the plants from cold and storms, allow for an abundance of direct sunlight, provide for ventilation and in most

cases they must be equipped with facilities for artificial heating.

In a general sense, the term greenhouse refers to those glass structures used for the growing of plants. They are for the most part above ground and are house-like in appearance. There is, however, another general class of glass structures also used for the growing of plants but which are low and often almost wholly under ground. Unfortunately, there is no general term commonly applied to them as a class, but since it is common to use in their construction certain standard-size glass sash, the author ventures to suggest the term sash-bed as a general one to include structures of this class; and it is so used in this book.

CLASSES OF SASH-BEDS*

Hotbeds.—These are low structures, being almost wholly under ground, but having a glass roof made up of sash which are of convenient size to be lifted off, so that the grower may care for the plants. They are usually warmed by the heat generated by decaying vegetable matter, commonly horse manure.

*For details see Chapter II.

Their chief use is for starting plants in early spring.

Coldframes.—These are similar to hotbeds but are seldom heated and may therefore be of more shallow construction, as no pit is needed to store the manure. Their chief use is for the growing and protection of young plants after they have been started in hotbeds or forcing houses, or for the growing of plants in late spring after danger of severe weather has passed.

Coldpits.—These are deep pits chiefly used for the storing of bulbs and semi-hardy plants during the winter. They are usually provided with sash roofs the same as hotbeds and coldframes, so that light may be admitted when desired.

CLASSES OF GREENHOUSES

Forcing Houses.—These are greenhouses used for growing or "forcing" plants at other times than at their natural seasons. Practically all houses used by commercial florists and vegetable growers are forcing houses.

Conservatories.—In this class of greenhouses, plants are kept mostly for display. Often it is not desired that the plants so kept

shall grow rapidly, but that they shall merely live. Often also they house for the most part such semi-hardy evergreen and other ornamental plants as may be grown outside during the summer. Such houses are common in parks and private estates. They are usually ornamental in character, often with curved roofs, and present a lively contrast to the severe simplicity of the commercial forcing houses.

Propagating Houses.—These houses are devoted principally to the propagation or starting of plants, especially those grown from cuttings. As cuttings require little direct sunlight, these houses are often erected on the shady (north) side of other greenhouses or in out-of-the-way places. They should be equipped with benches, underneath which the heating pipes should be placed to furnish "bottom heat."

The term HOTHOUSE, as commonly used, is a general term synonymous with greenhouse, and may be applied to any of the above classes.

The term STOVE HOUSE is an old one, originally applied to any greenhouse used for tropi-

cal plants and thus of necessity kept at a high temperature. The use of this term is more common in England than in this country.

A RANGE of greenhouses implies several houses more or less closely connected and under one management. The individual houses may be of any one of the classes mentioned above or a combination of two or more classes. Such houses are often spoken of as a RANGE OF GLASS.

A range of forcing houses is sometimes spoken of as a BATTERY, and a range of sash-beds as a NEST.

EVOLUTION OF THE GREENHOUSE

It is said that the Romans, even before the time of Christ, possessed some knowledge of the forcing of fruits and vegetables, and utilized for this purpose pits covered with slabs of a transparent mineral. Heat was supplied by fermenting manure, and occasionally by furnaces of masonry in which a slow fire of wood or dried manure was kept burning. How successful they were we do not know; but it seems certain that if any degree of perfection was obtained, it was because of the skill of the gardener rather than because of any special merit of the forcing pits.

Forcing houses seem to have had their origin in an attempt to grow in the northern countries of Europe fruits such as the orange and grape, which were grown to such perfection in the countries to the south. Thus in England the grape vine is hardy, but the summers are too cool and the seasons too short to ripen the fruit to perfection. This led to the training of the vines on the south side of buildings and walls that they might receive more fully the light and heat of the sun. Later there was conceived the possibility of still further protecting them by the use of glass sash leaned against the wall. From this it was an easy step to the building of a rather permanent framework close to the walls, on which glass sash were placed when required, forming a closed house. Sometimes the walls were made hollow and slow fires built within them to give additional heat. Finally the idea of heating the air instead of the walls on which the vines were trained resulted in the building of brick and stone stoves or fireplaces within the glass enclosures. These houses were never intended for winter use, but simply to make the summer and fall conditions similar to those farther south.

The attempt to grow the orange in these northern climates presented a different problem because the trees had to be protected during the winter. This resulted in the building of framework structures which were covered during the winter with wooden shutters and heated by means of a stone fireplace. There was little or no glass used, but the shutters were removed during the summer, leaving nothing but the framework to obstruct the light and heat of the sun. A house of this description, built early in the 17th century by one Solomon de Gaus at Heidelberg, Germany, is said to have been 32 feet wide and some 400 feet long, and to have sheltered 400 orange trees.

The next decisive step in the evolution of the modern greenhouse seems to have been a combination of the two preceding types, designed for the growing of plants during the winter. They were permanent buildings having opaque roofs and high side walls, resembling dwelling houses, except that they were well supplied with side windows.

At this time it was thought necessary to have opaque roofs to prevent freezing, and it became common to have a second story, which was used as a dwelling by the garden-

er, in order to prevent the heat from escaping or the frost from "entering" through the roof. It was not until the early part of the 18th century that glass roofs were found to be practicable, and they were even then slow in coming into use.

The first greenhouses in this country suggestive of the modern forcing house came into existence toward the close of the 18th century. For the most part they were narrow houses of the shed-roof type, having a solid wall to the north and a glass roof sloping to the south. They were warmed by flues, usually of brick, passing through the entire length of the house, and connected with a brick fireplace at one end and a chimney at the other. Following this, there came in rapid succession, improvements in form and methods of construction and especially in heating, both steam and hot water being used early in the 19th century.

The real progress in greenhouse construction in this country came with the industrial development of the country after the Civil War. The United States census reports show that there was but one commercial greenhouse prior to 1800; only three prior to 1820,

and only 178 in 1860. It was not until 1890 that greenhouses had assumed sufficient importance to secure a place in the census reports. At that time there were 4,659 establishments covering 38,823,247 square feet, valued at $38,355,722.

The following table shows the total number of square feet under glass in the United States and ten principal states, as shown in the census reports for 1910, 1900 and 1890. The rank of the states has changed materially during the past 30 years.

AREA UNDER GLASS IN THE UNITED STATES AND TEN PRINCIPAL STATES. FROM CENSUS REPORTS

	1910		1900		1890
	Tot. Glass sq. ft	Greenh'ses sq. ft.	Tot. Glass sq. ft.	Greenh'ses* sq. ft.	Tot. Glass sq. ft.
U.S.	114,665,276	105,165,730	96,230,420	80,544,862	38,823,276
Ill.	15,950,853	14,380,857	8,744,020	7,318,744	3,236,750
N. Y.	15,066,587	13,878,875	13,635,440	11,412,863	6,947,289
Penn.	13,846,672	12,887,672	11,819,610	9,893,013	6,066,144
N. J.	8,840,511	7,984,752	11,190,250	9,356,283	3,703,554
Ohio	7,583,562	7,091,976	7,970,190	6,471,049	2,785,192
Mass.	7,382,009	6,817,585	8,710,280	7,290,504	2,717,946
Cal.	5,087,132	4,422,423	1,572,480	1,316,165	
Mich.	4,122,099	3,922,772	2,593,230	2,170,233	1,293,443
Mo.	2,812,221	2,545,138	3,126,400	2,616,786	1,240,095
Iowa	2,183,182	1,870,840	1,436,260	1,202,149	
Ky.					1,163,241
Conn.					1,060,920

*Estimated.

CHAPTER II

SASH-BED CONSTRUCTION

HOTBEDS

As stated in the preceding chapter, hotbeds are low structures almost wholly under-

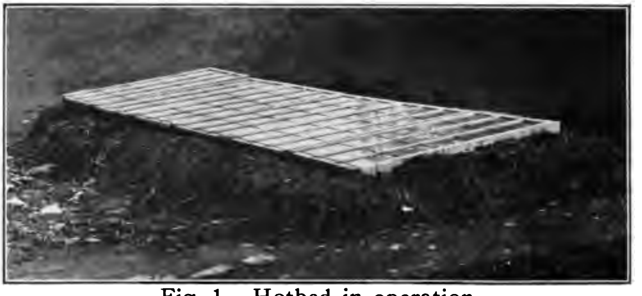

Fig. 1.—Hotbed in operation

ground, but having a glass roof made up of sash. They are usually heated by fermenting horse manure placed in the bottom, but may be heated by brick or tile flues, or by steam or hot water. Their chief commercial use in for the starting of early vegetable and flowering plants. In the home garden they may be used for growing to maturity in early spring or late autumn, such semi-hardy and

quick maturing vegetables as radishes and lettuce, and thus extend the season for several weeks or even months. They may also be used for starting and protecting early in the season, other slower growing crops such as melons, which are not transplanted but are allowed to mature in the beds. A gain of several weeks may thus be secured in the time of ripening. Well constructed and protected hotbeds will withstand a temperature as low as zero if it is of short duration.

Location.—The location for the hotbed should be (1) relatively high; (2) well drained; (3) exposed to the sun throughout the day; (4) protected from north and northwest winds; and (5) either comparatively level, or sloping toward the south or southwest. For convenience it should be near some building which may be used as a workroom, and should be close to a supply of water. The south side of a building is often an ideal location, although there is some danger, if the building be a light colored one, that the hotbed may become overheated.

Sash.—Standard hotbed sash are 3 x 6 feet, and from 1⅜ to 1⅞ inches thick, the latter being more durable but heavier to

handle. Since they are subjected to especially rough usage, they must be well constructed of good material, and must be kept well painted. Well constructed sash may be secured from any reliable dealer in greenhouse

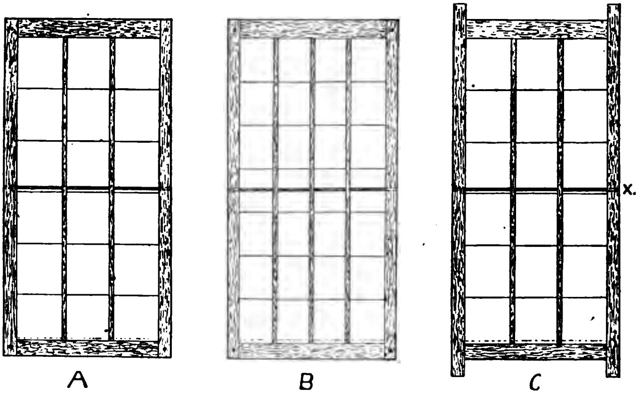

Fig. 2.—Standard Hotbed Sash
A, three run sash; B, four run sash; C; Horned sash; X, iron rod to keep sash from spreading

material. They may be of either cypress or cedar and have mortise and tenon joints, though the tenons should not extend quite through the bars, or they will be more likely to absorb moisture and thus decay rapidly. All joints should be painted with thick lead paint and should be put together while the paint is green. Sash with a light iron rod or bar across the middle, connecting the side

bars, will usually prove to be more durable, as the rod prevents the sides from spreading.

Most hotbed sash consist of three rows of glass so laid that the water will flow lengthwise of the sash. For this purpose 18 panes of 10 x 12-inch glass are required. Sash having four rows of glass are not uncommon, but the extra bar and laps obstruct so much light that they are less satisfactory, and they are rapidly going out of use. They require 28 panes of 8 x 10-inch glass. Sash may be purchased either glazed or unglazed. When time is plentiful and the workman is handy with tools, they may be glazed at home at a considerable saving in cost.

Well made sash may be had, unglazed and unpainted, at from $1 to $1.25 each. The same sash glazed and painted cost from $3 to $3.50 at the factory. The price of glass varies greatly from year to year, but on the average will cost from 75 cents to $1 per sash. Roughly speaking, the sash, putty and paint will cost about $2.25, leaving from 75 cents to $1.25 for the labor of glazing and painting. Sash of varying sizes are sometimes seen, but their use is not advised. It is seldom possible to replace them as cheaply as when standard size sash are used.

When sash are glazed at home they should first be primed with a coat of lead paint. On looking them over it will be observed that one of the end bars is not so thick as the other, the upper surface being in line with the bottoms of the grooves or channels made to receive the glass. This is the lower end of the sash and should always be placed toward the south. The glazing also begins at this end. In glazing, the first pane is laid flat, the bottom of the second lapped over the top of the first and so on, small brads or glazing points being placed at the lower end of each pane and along the sides to hold them in place. Since the lap obstructs the light it should be as narrow as possible, an eighth of an inch being as wide as necessary. In order to obviate the necessity of cutting the last glass to keep the laps even, it is well to lay all the panes for one row on loosely, and to space them before fastening any. They should then be puttied the same as ordinary windows, and thoroughly painted.

A more satisfactory way of setting the glass is to bed them in putty as described in Chapter VII, but this method is rarely used with hotbed sash. Sometimes the glass are butted; that is, they are laid flat, end to end,

instead of lapped. This is rarely satisfactory for hotbed sash; because (1) the panes are often not squarely cut and do not fit well, and (2) the sash have so little pitch or slant when in use that water is apt to run through between the panes.

Some makers offer a form of sash known as "horned sash," in which the side bars extend two or three inches beyond the end bars. These extensions make convenient handles for carrying, and it is claimed that a better joint can be made than when they are cut off flush with the end bars.

Double-glass Sash, as the name implies, are constructed with two layers of glass with an air space of about a half-inch between. They have certain advantages over single-glass sash which may be stated as follows: (1) They give greater protection; (2) they reduce labor, as it is not necessary to use

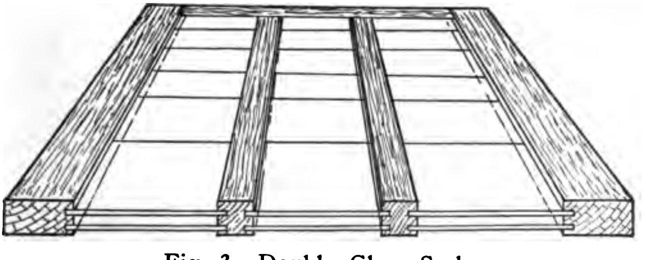

Fig. 3.—Double Glass Sash

mats as late in the season; (3) in moderate climates no mats or supplementary protection is needed; (4) the plants receive sunlight during the entire day when mats are not used, whereas, with single glass sash, the mats have to be left on until the sun is well up and then have to be replaced before sundown.

On the other hand, they have several disadvantages: (1) The first cost is often as much as 50 per cent. greater; (2) they are heavier to handle; (3) they reduce the amount of light, especially if the glass becomes loosened so that dust accumulates between the layers; and (4) some users complain that they are short-lived because moisture collects between the layers and promotes rapid decay.

The most enthusiastic supporters of these sash are those who live in climates where this type of sash never need supplementary protection, but where it is not safe to leave single-light sash unprotected. It is but fair to state, however, that their use is rapidly increasing, even in the north.

Temporary Sash, made of oiled paper or treated cloth, are sometimes used for special

purposes and give more or less satisfactory results. Directions for making will be found in Chapter VII.

The Pit.—As most hotbeds are heated by fermenting manure, a necessary part is a pit of some depth in which it may be placed. This pit may be lined with boards, plank, brick, stone or concrete, the latter being the most satisfactory. Cypress, cedar, chestnut and black locust are the most durable, moderate price woods for this purpose. For data on concrete construction see Chapter XV.

The depth of the pit is determined by: (1) The severity of the climate and (2) the kind of plants to be grown. As more heat is produced for a longer time from a deep pit of manure than from a shallow one, it is evident that in cold climates and for plants requiring considerable heat, such as tomatoes and peppers, the pit must be deeper than in warmer climates, or for plants like cabbage or cauliflower which may be grown at lower temperatures. For starting early vegetable plants in late February or early March in the north, 24 inches of manure will be required, whereas in milder climates, or later in the season, 12 to 18 inches will be suffi-

cient. The manure will continue to give off heat for three to six weeks.

The dimensions are determined by the sash. Since sash are 6 feet long and are constructed to slope lengthwise rather than crosswise, the width of the pit north and south should be a trifle less than 6 feet over all. The length is determined by the number of sash desired. Since they are 3 feet wide, it should be some multiple of three. For example: A two-sash bed would be 6 x 6 feet, a three-sash bed 6 x 9 feet, etc. It is essential that the pit be well drained either naturally or artificially. If it is to be used in early spring, it is made the previous fall, filled with straw or manure and covered with boards to keep out rain and snow. When the bed is to be made this material is removed, leaving an unfrozen pit in which the new manure will heat more evenly and be more efficient.

The upper or north side of a permanent hotbed is preferably 6 or 8 inches higher than the south side to give the proper slant to the sash. The north side may be about 15 inches and the south side about 9 inches above the surface of the soil. The sides are connected with crossbars placed

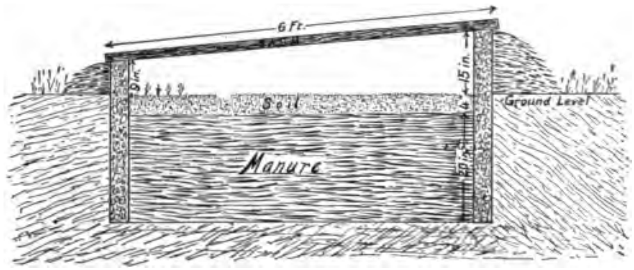

Fig. 4.—Plan for permanent hotbed

even with the top, 3 feet apart, to serve as rests for the sash and to keep the frames from spreading. The sides and ends of the frame are well banked with fresh manure to conserve the heat. If the plants are to

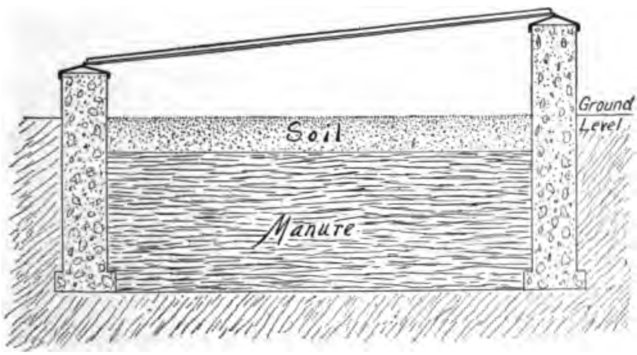

Fig. 5.—Permanent hotbed of concrete with cast-iron sills

be grown in flats instead of directly in the soil, 2 inches of soil over the manure will be sufficient. If the plants are to be grown in the soil it should be 4 or 5 inches deep.

Temporary hotbeds are sometimes made by piling the manure on the surface of the ground and placing a shallow frame on top.

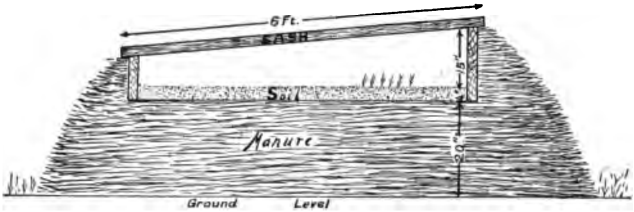

Fig. 6.—Plan for temporary hotbed.

This form is wasteful of manure, and the settling of the pile is likely to warp the frame so that the sash will not fit tightly. It is most often used when a hotbed is needed and a pit has not been dug the previous fall.

Another method is to dig a pit somewhat larger than the frame. This is filled with manure to a little above the ground level.

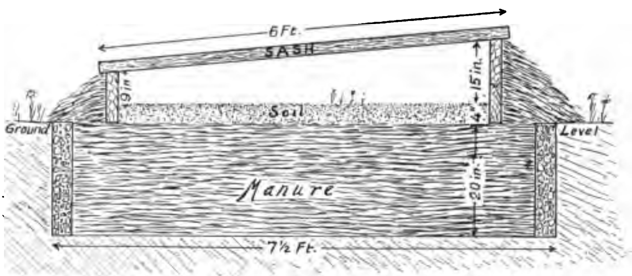

Fig. 7.—Type of hotbed used when a large amount of heat is required for a long time

On top of this is placed a frame. The advantage of this form of bed is that the frame settles with the manure, thus keeping the plants always the same distance from the glass. They are also warmer on account of the greater quantity of manure used.

Manure for Heating.—Horse manure is almost universally used in hotbeds, the pro-

Fig. 8.—Usual type of concrete hotbed

portion being about two parts solid excrement to one part straw or leaves. Manure which contains shavings is not satisfactory. Preparation is made 10 or 12 days before the beds are wanted. The manure must be freshly made and if not moist is dampened, preferably with warm, though not hot water. More than enough manure to fill the pit is provided, for it will shrink somewhat in vol-

ume, and some will be needed to bank the sides and ends. It is placed in layers in a pile 4 or 5 feet wide, about 4 feet high and as long as necessary to contain the required amount, each layer being lightly tramped as placed. This is done under cover if possible.

After two or three days, or as soon as the pile begins to steam, it is re-piled, the outside of the first pile being placed into the center of the second to encourage even heating throughout. The manure is moistened with warm water if it has become dry. If properly made a vigorous fermentation will have set in after two or three days and it is then ready to be placed in the bed. If not thoroughly warmed through in three or four days after the second handling, it is re-piled again every few days until fermentation is established. Poor heating qualities may be the result of: (1) Manure from poorly-fed horses; (2) cold weather; (3) too wet or too dry manure; (4) too much litter in the manure and (5) shavings or swamp hay used as litter instead of straw or leaves.

If a steady heat for several weeks is required, the manure is placed in the pit in thin layers and trampled quite solidly, especially

along the sides and in the corners, keeping it as level as possible. Unless the hotbed is made so that the frame settles with the manure it must be filled to within 2 or 3 inches of the top of the south side of the frame to provide for settling. If it is properly made, the temperature will soon rise to 120 degrees or more, but will gradually fall, and when it reaches 90 degrees the seeds may safely be sown. The temperature may be determined by plunging a reliable thermometer through the soil into the manure.

When a hotbed is arranged to be heated by flues, drain or sewer tile is used, and the flues are connected with a fireplace at one end

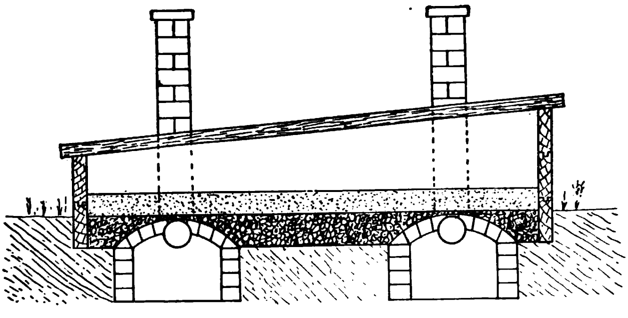

Fig. 9.—Hotbed arranged for heating by flues

of the bed and a chimney at the other, so that the smoke and heat from the fire travel the whole length of the bed. Hot water or

steam pipes may be run through these flues if desired, or they may be placed along the sides of the frame above the soil.

COLDFRAMES

The forcing house, because of its convenience, possibility of heat regulation and comparative cheapness of operation is rapidly taking the place of the hotbed in a commercial way in the starting of early plants, but it is promoting the use of coldframes. These structures rarely receive artificial heat and

Fig. 10.—A good type of coldframe with angle iron corners, A.

are used largely for the purpose of growing and protecting plants during mid or late spring, after they have been started in the hotbed or forcing house and until they are ready to plant in the open. They are, in reality, simply hotbeds without artificial heat. When banked with manure and protected with mats, these frames will protect tender plants at temperatures of 15 or 20 degrees below freezing, if of short duration.

The best frames are made of cypress and are joined at the corners by means of angle irons and bolts so that they may be easily taken apart for storage.

Fig. 11.—Coldframe with sash removed. The sash rest on the crosspieces, X.

When large numbers of frames are used in relatively mild weather, they may be very cheaply constructed by placing two planks parallel to each other and 6 feet apart. The plank on the north side is 12 inches wide and the one on the south side 6 inches wide. When the plants are removed the planks may be taken up and stored, or allowed to remain, and crops may be planted between them.

In mild climates, coldframes may be utilized for starting early plants before danger from frost is over, although it is often

advisable to equip them with steam or hot water pipes, so that they may be heated in case of emergency. In the north, coldframes are used for wintering violets, pansies and other semi-hardy plants; and farther south, for wintering cabbage, cauliflower and other plants which are started in the fall.

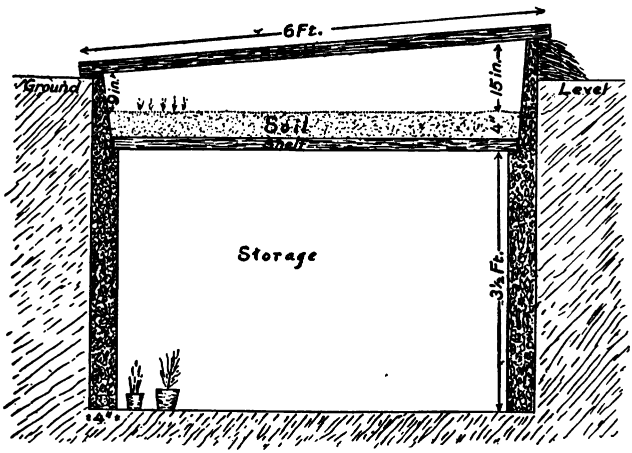

Fig 12.—A cold or storage-pit with shelf for growing violets

COLD OR STORAGE PITS

In almost every florist's or vegetable grower's establishment there is need for an out-of-the-way frost-proof storage, to which light may be admitted on occasion. Such a stor-

age may be easily constructed by excavating a pit similar to a hotbed pit, but deeper, so that the bottom will be well below the frost line. This must be well drained and lined with a brick or concrete wall, which should extend a few inches above the natural ground level to prevent water running in at the top, but is banked at the top with soil or manure. The pit may then be covered with sash and protected with mats and shutters described in a succeeding paragraph.

In cold climates the pit is at least 5 feet deep. In very severe climates a mulch of manure 6 inches deep placed for a distance of 4 or 5 feet around the pit before the ground freezes, will effectually protect it. As the normal winter temperature of the soil below the frost line is considerably above freezing, coldpits furnish excellent storage for gladiola, dahlia and similar plants, and also for bulbs for winter forcing. A row of storage pits and coldframes along the south side of a greenhouse is of great convenience. The house must be provided with a gutter, or the frames set a foot or more away from the side of the house to guard against breakage

by snow or ice falling from the roof. A pit may be attached to the south side of a dwelling and connected with the basement. When the house is heated by a furnace this may be easily heated with little expense, and be used for growing vegetables or flowers throughout the winter.

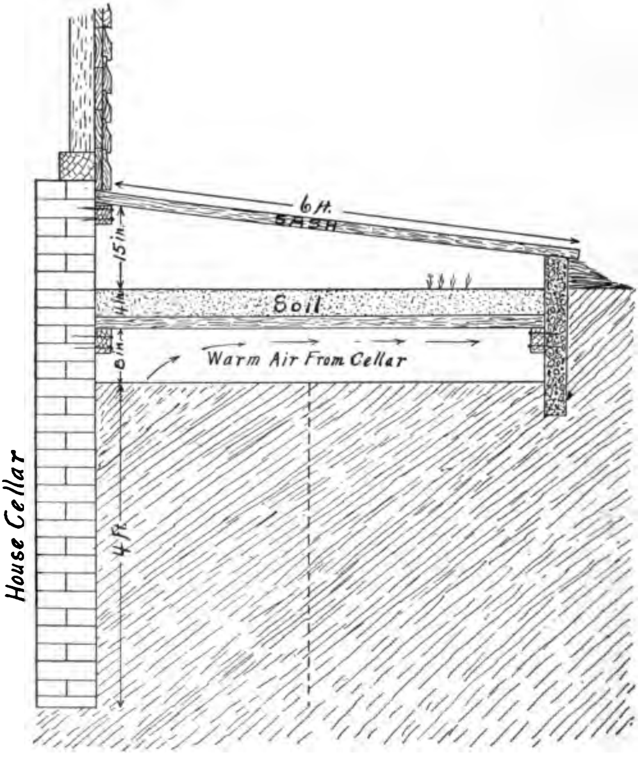

Fig. 13.—Sash-bed attached to basement of dwelling

FORCING BOXES

Forcing boxes or plant forcers are small coldframes with a single pane of glass, which are used to place over individual plants started early in the spring. They are used

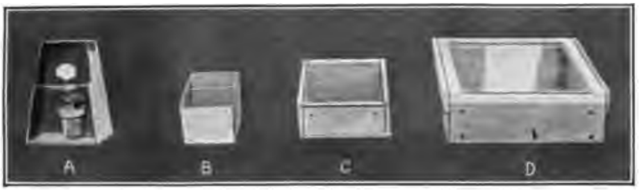

Fig. 14.—Types of forcing boxes or plant forcers

for protecting tomatoes, eggplants, melons and other heat-loving plants, and are removed as soon as continuous hot weather arrives. They are used also for forcing rhubarb, asparagus and other vegetables in early spring, and for perennial flowering plants.

Fig. 15.—Forcing boxes in use on a commercial scale

GABLE ROOF SASH-BEDS

Sometimes hotbeds and coldframes are made of two rows of sash set so as to form a gable roof. They have few advantages and many disadvantages when compared

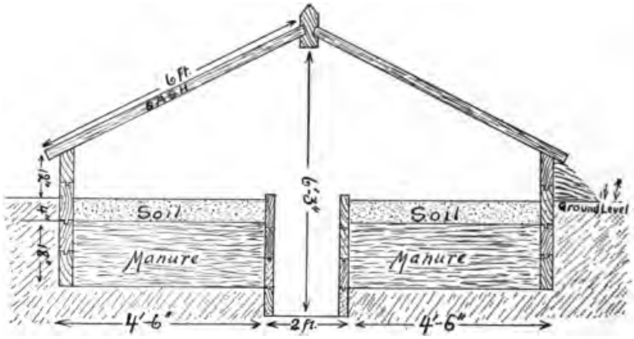

Fig. 16.—Gable roof sash-bed heated by manure

with those of the ordinary type. A few years ago it was quite common to find sash-beds of this kind with a sunken walk under the ridge in which the workman could stand, the heat being supplied by decaying manure the same as in an ordinary hotbed. Such beds are convenient to operate in planting, watering and cultivating, especially in cold weather. They are not a profitable venture as a rule, as heat can be supplied more cheaply from coal than from manure. When an investment has been made in a house of this

type it will be found to be economy to equip it with an inexpensive hot water system.

MATS AND SHUTTERS

Hotbeds and coldframes, when used in climates or seasons in which the temperature is likely to fall much below freezing, must be provided with supplementary coverings.

Fig. 17.—Rye straw mats rolled for storage

This is especially true when single-light sash are used.

Rye Straw Mats, are extensively used for this purpose. They were formerly made by hand but are now made by machinery and are fairly reasonable in price. Each mat is

designed to cover two sash and should be 6 x 7 feet to allow for turning over the ends of the sash to keep out the wind. An objection to straw mats is their weight, especially when wet, and also the fact that mice are likely to work in them while they are stored during the summer. With careful handling they will last three or four years.

Fig. 18.—Hot-bed covered with (C) double glass sash; (B) sash and straw mat; (A) sash, straw mat and shutter

Burlap and Canvas Mats, which are padded with waste cotton and quilted, are easier to handle than straw mats and are somewhat more durable. Though usually thinner than straw mats, they give practically as good protection. They have the added advantage of requiring less storage space, and are some-

times treated with tar or other material offensive to mice.

Waterproof Mats, made of heavy canvas, or sometimes of oiled or rubberized fabric, seem to have but little advantage over common mats, except on coldpits, when they are to be used during the entire winter. They are relatively expensive.

Wooden Shutters, 3 x 6 feet in size, made of half-inch lumber, are occasionally used to place over the mats. Their chief value is in protecting hotbeds when made very early in the season, and for coldpits.

Care of Sash-bed Materials.—As hotbeds, coldframes and the like, are used for only a few months during the year, they are likely to be neglected and thus deteriorate rapidly. When many are used, their proper care may spell the difference between financial success and failure.

If movable frames are used, they should be taken down and stored as soon as the plants are out. If they are so constructed that they do not come apart, easily, they may be piled one above the other, cleaned and painted.

Sash should be cleaned and stacked under cover. Rainy days may be utilized in painting them and re-glazing where necessary. It is economy to re-paint sash every season.

Mats must be handled carefully and dried as soon as possible after they become wet by hanging them on a line or fence. They must be thoroughly dry when stored for the summer and be kept where mice cannot get to them.

CHAPTER III

THE GREENHOUSE PROPER—GENERAL CONSIDERATIONS

Location.—Having determined upon the geographical location, proximity to market and fuel supply and the investment in land which the business may be expected to warrant, all of which are without the scope of this discussion, the points next to be considered in the location of a greenhouse are as follows: (1) It should be such that the sunlight will not be obstructed at any time during the day. The probability of high buildings being erected in the immediate vicinity should be taken into account. (2) It should be well drained either naturally or artificially and be absolutely free of danger from floods. (3) It should not be exposed to cold, bleak winds, as they will quickly make their presence known in excessive fuel bills. A wind break of evergreen or other trees will be found very effective in protecting from winds but it will be several years before the trees will be large enough to be of much benefit.

(4) It should be comparatively level, or gently sloping toward the south or southeast. Hillsides, if necessary, may be utilized by building houses of special design to be described later. (5) An unfailing supply of water at a reasonable cost should be assured. (6) If the houses are to be erected in connection with other buildings, they should be on the south side if possible. For most plants the advantage of direct sunlight during the whole day cannot be over-estimated. (7) The possibility of enlarging the range by the addition of more houses should not be overlooked.

Arrangement.—The arrangement will depend to some extent on the size of the range and the purpose for which it is to be used. If for private use only, convenience may often be sacrificed for appearance; but for the commercial house the first thought in arrangement is for economy in operation.

For a commercial house the following points in arrangement should be considered: (1) The direction in which the houses are to run. This will be fully discussed in Chapter IV. (2) The distance between the houses. This will depend on the size and height of the

Fig. 19.—Private range of C. E. Chapman, Oakdale, N. J. Erected by Hitchings and Company

houses and on the value of the land. Little advantage, except in case of heavy snowfall, will be gained over the ridge-and-furrow system (see Chapter IV) by separating the individual houses by less than 10 or 12 feet. A fair though not absolute rule is to space the

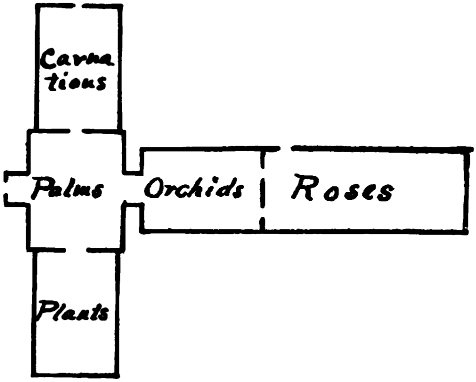

Fig. 20.—Ground plan of range shown in Fig. 19 —Boiler room is in basement

houses at a distance equal to two-thirds their height. (3) The workroom should be convenient to all houses of the range, yet shade them as little as possible. (4) Other things being equal, the boiler room should be at the lowest part of the range in order to secure good circulation. When the houses are long it is usually best to have it near the center, and to insure circulation by deepening the

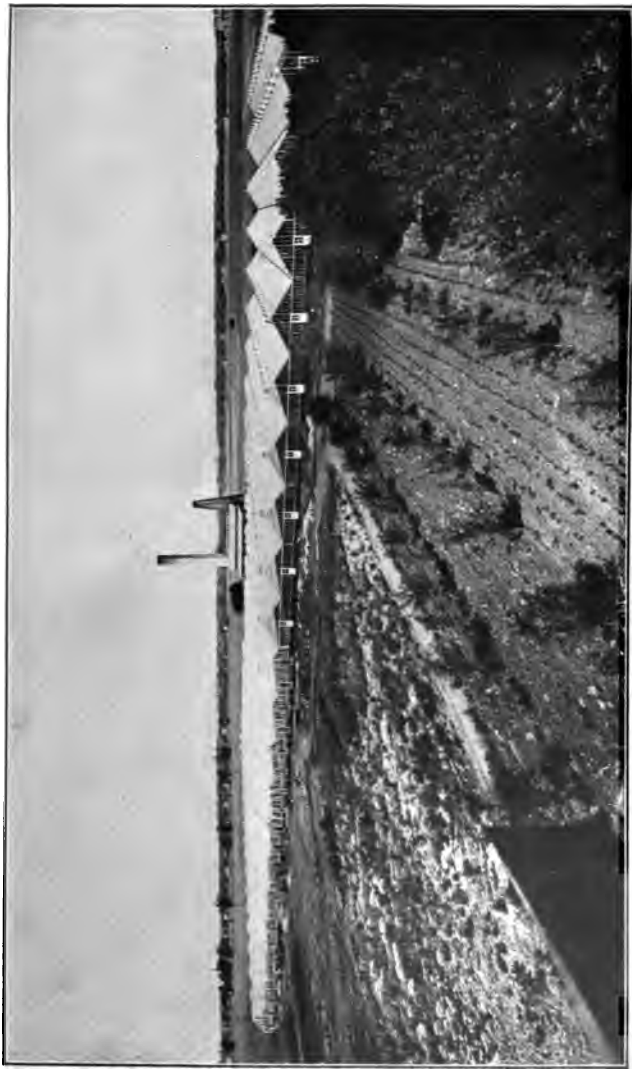

Fig. 21.—Commercial range of Hoerber Bros., Des Plaines, Ill. Erected by J. C. Moniger Co. (A typical commercial range)

boiler pit, or in large establishments by the use of pumps or steam traps which will be discussed in the chapters on heating.

Size of House.—There is no authentic data on the comparative efficiency of small and large houses. The large houses are relatively lighter, but there are other considerations.

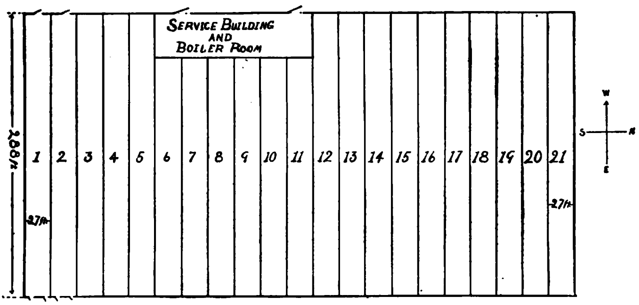

Fig. 22.—Ground plan of range shown in Fig. 21

As a rule the eastern growers favor separate large, high and wide houses while those of the Middle West prefer lower and narrower connected houses. The present tendency is to build larger houses than formerly. Of 160 florists and vegetable growers whom the author has consulted, 148 or 88 per cent. expressed themselves in favor of houses ranging from 24 to 40 feet in width. These are undoubtedly the most popular widths at the present time, the length varying from 100

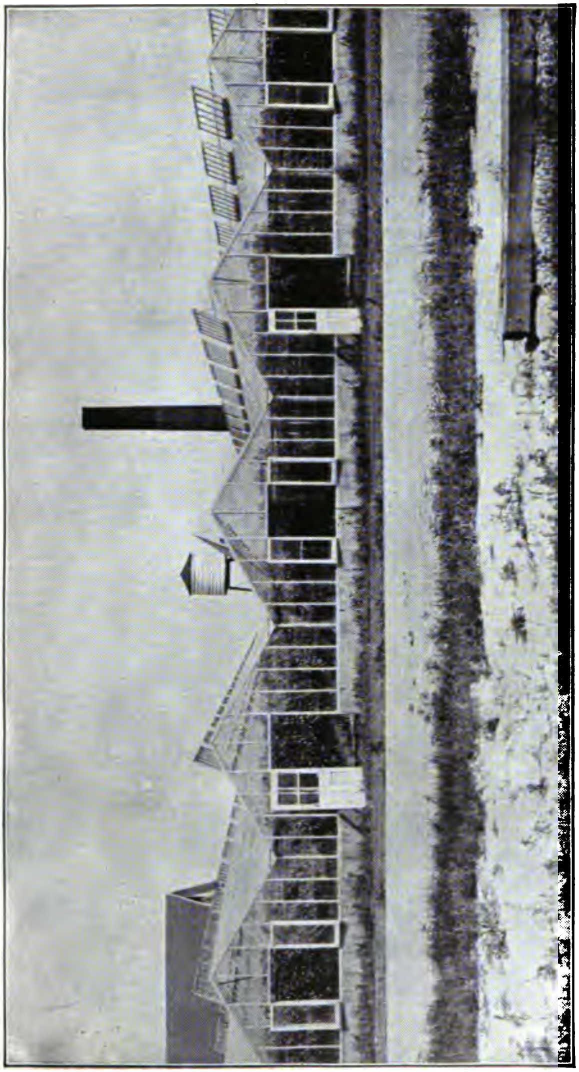

Fig. 23.—Part of the vegetable forcing range of Searls Bros., Toledo, Ohio, showing the narrow connected houses common in the Middle West

to 500 feet or more. A discussion of the advantages of high, wide, single houses and of low, narrow, connected houses is given in Chapter IV.

Pitch of Roof.—The pitch of a roof means the degree of slant or the angle of divergence from the horizontal. The glass of the roof not only allows the light, heat and chemical

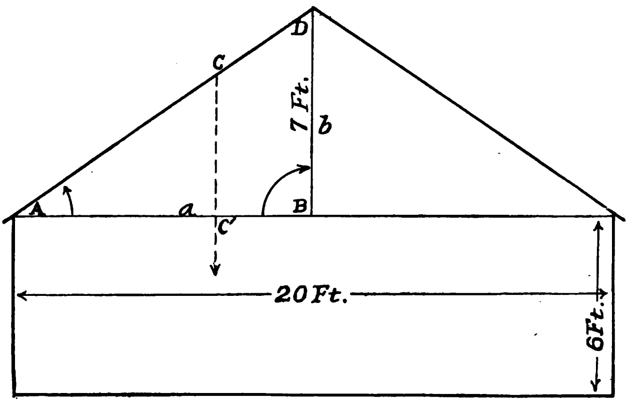

Fig. 24.—The pitch of the roof is measured at A

rays to pass through it, but it also acts to some extent as a mirror, thus reflecting a part of the rays. The amount lost by reflection is proportional to the angle of incidence. Thus, if the sun's rays fall upon the roof at right angles, little or none is lost by reflection; but when they fall at a less

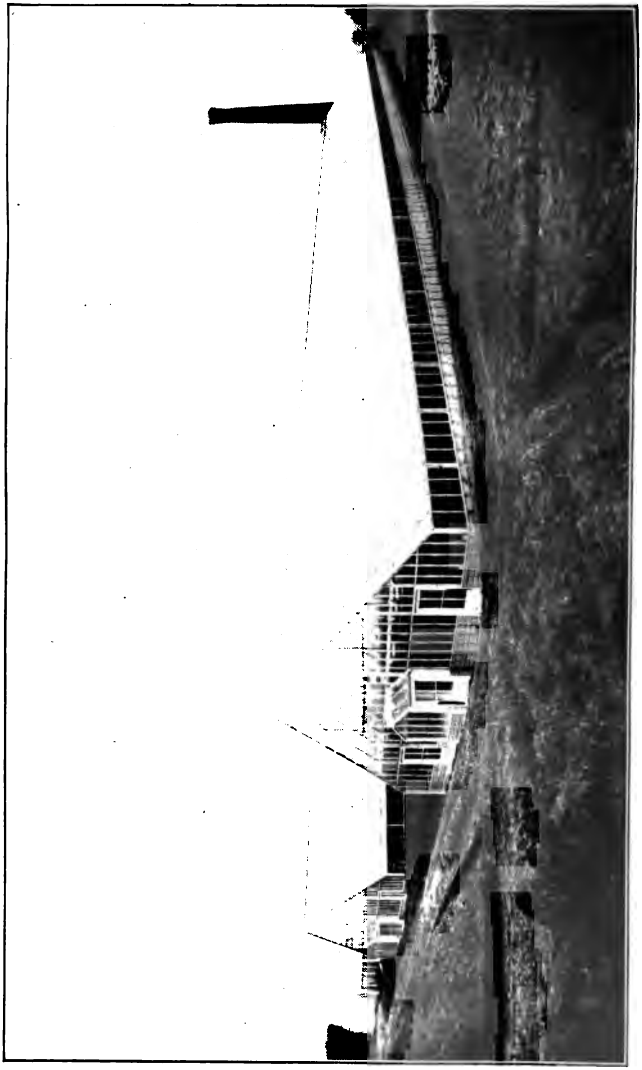

Fig. 25.—Commercial range of C. H. Metcalfe, Milford, Mass., showing the wide, separate houses preferred by eastern growers

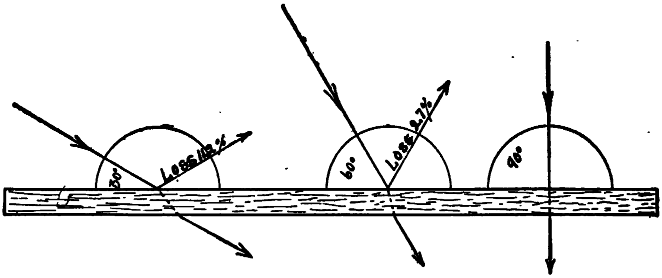

Fig. 26.—Diagram showing how heat and light are lost by reflection

angle, the amount reflected increases as the angle of incidence increases. The amount of the sun's energy lost by reflection when the rays strike the roof at various angles is shown in the following table.

Table showing per cent. of sun's energy lost when the rays strike the glass at different angles

Angle of ray	Loss by reflection
60 degrees	2.7 per cent.
50 "	3.4 " "
40 "	5.7 " "
30 "	11.2 " "
20 "	22.2 " "
15 "	30.0 " "
10 "	41.2 " "

It is apparent that the maximum amount of the sun's energy may be secured by a roof presenting to its rays an angle of 90 degrees. It is especially important that the energy

of the sun be conserved during the short days of winter. At its lowest period the sun rises, in the latitude of New York, scarcely more than 25 degrees above the horizon at noon. In order for the roof to present an angle of 90 degrees to the sun's rays at this season, it would need to have a pitch of 65 degrees.

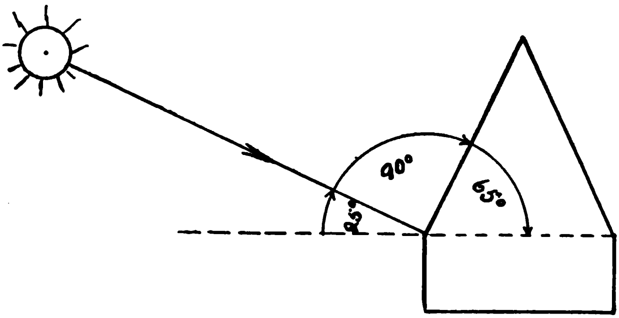

Fig. 26a.—Diagram showing pitch of roof necessary to present an angle of 90 degrees to the sun's rays in winter

Such a roof would be (1) very expensive to build and maintain, (2) would present too large an amount of radiating surface for the space covered and (3) would be too high to be practical in houses more than 10 or 15 feet wide.

If, however, we reduce the pitch to 35 degrees, the sun's rays will strike the roof at an angle of about 55 degrees which, by reference to the table, will be seen to incur a loss

by reflection of between 2 and 3 per cent. only. Roofs of this pitch are not difficult to build, and do not present so large a radiating surface for the area covered as do roofs having a pitch of 65 degrees. Roofs having a pitch of less than 26 degrees are seldom satisfactory because the snow does not clear from them well and they are likely to leak.

The water of condensation which forms on the inside of the roof is also likely to drip upon the plants when the pitch is less than about 26 degrees. When the pitch is greater, the water will usually follow down the glass to the edge of the house. In even-span houses (see Chapter IV) the pitch of the roof varies from 26 to 35 degrees, 26 and 32 being the most popular. In some specially constructed houses it is as great as 45 degrees. Most builders equip houses up to 25 feet in width with roofs having a pitch of 32 degrees, and above 25 feet with roofs having a pitch of 26 degrees.

Measuring the Pitch.—The degree of pitch of any even-span roof may be determined trigonometrically when the width of the house and the height of the ridge is known or can be measured. If the house illustrated in

Fig. 24 is 20 feet wide and the ridge is 7 feet above the eaves, the value of the angle, known as A, may be found by the following formula: Tang. $A=\frac{b}{a}$ equals Tang. $A=\frac{7}{10}$ equals Tang. $A=.700$ or $A=35$ degrees.

Should the house be of uneven span it is only necessary to measure the distance corresponding to **a** (Fig. 24) and apply the same formula. When this is not convenient, a plumb bob may be dropped from any part of the roof, as at **c**, and the distance measured from the roof to the point c^1, where it cuts a horizontal line or straight edge from the point where the roof joins the wall. This distance may be substituted for **b** in the formula, and the distance from c^1 to the intersection of the roof and wall may be substituted for **a**. To avoid error the triangle thus formed should be as large as possible and care taken to see that the lines are perfectly vertical or horizontal, as the case may be. By referring to the following table the angles in degrees and minutes formed by roofs on houses of various widths and heights of ridge may be quickly found. The figures in the left-hand column correspond to half the width of even-span houses or to the distance represented by **a** in the above formula.

Table showing angle formed by roofs on houses of different widths and heights of ridge

One half width in feet	Height of ridge in feet 4 ° ′	5 ° ′	6 ° ′	7 ° ′	8 ° ′	9 ° ′	10 ° ′
6	32 21	39 48	45	49 24	....	....	....
7	29 44	35 32	40 36	45	48 49	....	....
8	26 33	32	36 52	41 11	45	48 32	....
9	23 57	29 3	33 5	37 52	41 38	45	....
10	....	26 33	30 58	35	38 39	41 59	....
11	....	24 26	28 36	32 28	36 2	39 17	42 13
12	....	22 57	26 33	30 15	33 41	36 52	39 41
13	....	....	24 47	28 18	31 36	34 42	37 34
14	....	....	23 12	26 34	29 44	32 44	35 34
15	....	....	....	25	28 4	31 00	33 40
16	....	....	....	....	....	24 13	26 32

It is perhaps more often desired to find the length of rafter necessary to form a roof of given pitch on a house of given width, than to determine the pitch of a house already erected. This may also be solved trigonometrically. For example: Suppose it is desired to know the length of rafter necessary to form a roof with a pitch of 35 degrees on a house 20 feet wide. If the roof is to be of even span, as shown in Fig. 24, we will have a right angle triangle, A B D, the base of which is known to be half the width of the house, or 10 feet. If the angle A is to be 35 degrees then: Cosine $A=\frac{10}{X}$ equals $.81915=\frac{10}{X}$. Transposing, $X=\frac{10}{.81915}$ or $X=12.2$ feet.

This formula is also applicable to an uneven span roof provided the distance from the point directly underneath the ridge to either side of the house is known. For example: In a 20-foot three-quarter span house, the base corresponding to **a** of the triangle A B D in Fig. 24 is either two-thirds or one-third of 20 feet, according to which side of the roof we wish to measure.

In the following table will be found the lengths of rafters required to form roofs of various angles on houses of different widths. The figures in the left-hand column correspond to half the width of an even-span house or the horizontal distance from the eaves to a point directly underneath, where it is desired to place the ridge.

Table giving length of rafters necessary to form roofs of various angles on houses of different widths

One half width of house in feet	Pitch in degrees						
	26½°	30°	32°	34°	35°	40°	45°
	LENGTH OF RAFTERS IN FEET						
6	6.67	6.92	7.07	7.23	7.32	7.80	8.48
8	8.90	9.23	9.44	9.65	9.76	10.70	11.31
10	11.12	11.54	11.79	12.06	12.20	13.05	14.14
12	13.35	13.84	14.14	14.46	14.64	15.60	16.96
12½	13.90	14.43	17.73	15.09	15.25	16.33	17.67
15	16.80	17.32	17.68	18.09	18.30	19.57	21.21
20	22.44	23.08	23.58	24.12	24.40	26.10	28.28
25	27.80	28.86	35.46	30.18	30.50	32.66	35.34

CHAPTER IV

GREENHOUSE ARCHITECTURE

Architecturally, the different forms of greenhouses are named and recognized mainly by the style of roof.

Lean-to or Shed-roof Houses.—These are the simplest forms of greenhouses; likewise the least expensive and least satisfactory. There is little excuse for building separate houses of this type, but they may be made to serve a useful purpose when erected against the side of a building or against a steep side hill. They usually extend east and west, with the high wall to the north and the roof sloping toward the south. For commercial purposes they are of little value, as they admit light from only one side, and but little direct sunlight, except for a few hours in the middle of the day. They may be utilized for growing ferns and other plants requiring little direct sunlight, also for starting early plants, or as grape or peach houses, the vines or trees being trained against the north wall.

Lean-to houses not only have the advantage over other types in less first cost, but also in cost of maintenance. They have less glass surface in proportion to the area covered; hence there is less breakage, and for the same reason they radiate less heat. For amateur use, especially when they can be erected against the south side of the dwelling, they may be built and operated at small cost and will afford much pleasure.

Even-span or Span-roof Houses.—In these houses, as the name indicates, the sides of the roof are of equal length. They are the most popular form, fully 80 per cent. of all houses of recent construction being of this type. They are superior to the lean-to in that they admit light from two sides, and also because they may be run either north and south, or east and west, as may be desired. On this point, however, practical growers disagree, some preferring the east and west arrangement, others the north and south. Theoretically, the points in favor of and against each seem to about counterbalance. They are stated in the following paragraph.

The north and south arrangement permits

direct sunlight to fall on both sides of the house for an approximately equal time during the day, thus giving all the plants in the house an equal chance. It also permits the workroom to be placed on the north end, where it will not shade the house. The principal disadvantage is that during the middle of the day, when the sun's rays are most potent, they strike obliquely against the roof and much heat and light is lost by reflection. Moreover, a large part is cut off by the sash bars and rafters.

In the east and west arrangement, the direct sunlight enters from the south side only, and in the morning and afternoon strikes the roof obliquely. During the middle of the day, when it is most effective, it strikes almost at right angles, although it is not evenly distributed and the plants on the north side of the house receive much less than those on the south side. This would seem to be a serious fault, but in practice is less serious than in theory. Of 110 growers whom the author consulted on this point, 38 were in favor of the north and south arrangement, 42 were in favor of the east and west and 30 expressed the opinion that there is little or no difference.

Fig. 27.—An uneven span house with a row of sash beds along the side

Uneven Span Houses.—The uneven distribution of light in even-span houses running east and west early led to the experiment of cutting off the north one-fourth, so as to make an uneven or three-quarter span house. The following advantages are claimed for these houses: (1) Thcy secure a more even distribution of direct sunlight to all plants. (2) The north span admits indirect light which insures better results than may be secured from a lean-to house. (3) The heat is more evenly distributed than in a lean-to house. They are often used in growing roses and other plants requiring a maximum of light. The construction of uneven span houses has been varied from time to time, the general tendency being to lower the north wall to approximately the height of the south wall. This arrangement insures even better distribution of light and does away with the necessity of elevated benches.

Uneven span houses are sometimes used for growing lettuce and other vegetables directly on the ground instead of in benches, especially on sloping locations. Modern greenhouses are so much lighter than the older types that the advantages of the un-

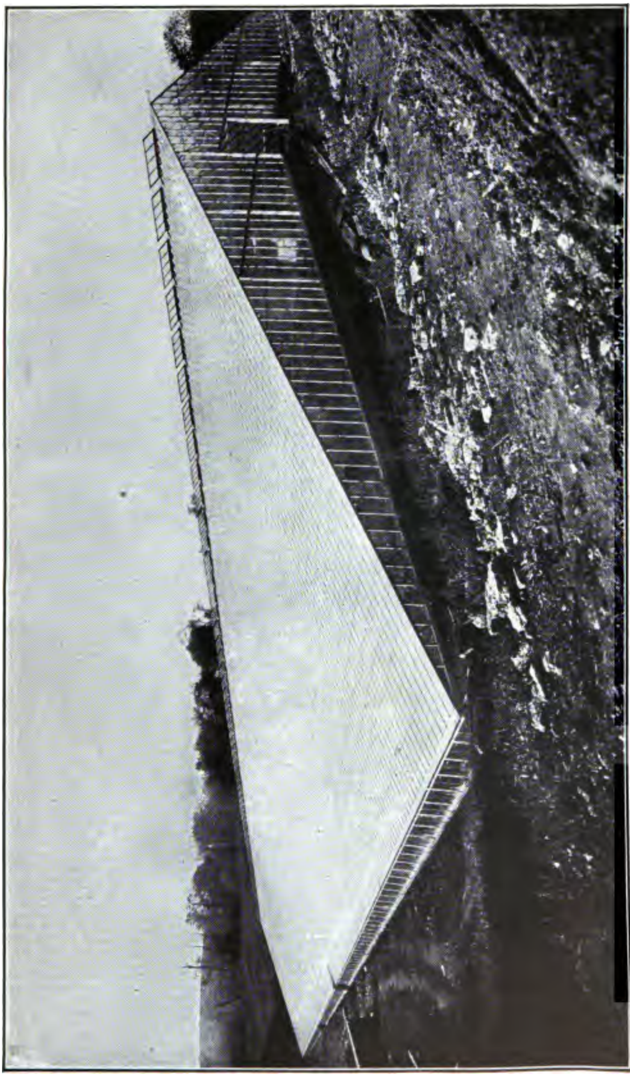

Fig. 28.—Uneven span side-hill vegetable house of W. H. Weinschenk, New Castle, Pa. Erected by J. C. Moniger Co.

even span house in this connection are hardly worth considering. They are much less commonly built than formerly. Uneven span houses are sometimes constructed with the short span to the south with a pitch of 40 degrees or more. This brings the roof more nearly at right angles to the sun's rays, but has little or nothing to recommend it.

Ridge-and-Furrow Houses.—A ridge-and furrow house is in reality simply two or more houses joined together. They may be even span or uneven span so long as the side walls are of equal height. The advantages of this form of construction may be mentioned as follows: (1) They are less expensive to build than separate houses of similar size, on account of the saving in side walls. (2) Not only is there a saving in the number of side walls, but the interior walls may be of cheap construction or may be left out entirely, the weight of the roof being supported by posts alone. (3) Considerable saving is made in labor because easy passage may be had between houses. (4) They conserve ground space which is often a considerable item. (5) The houses in the center are protected from wind by those on either side and the radiation is

thus reduced. (6) Because there is less exposed wall surface, and because the interior houses are protected, they require less fuel than do separate houses.

One of the chief objections to the ridge-and-furrow system of construction is the dif-

Fig. 29.—Ridge-and-furrow houses wrecked by a storm

ficulty of removing snow from between the houses in regions subject to heavy snowfall. Other disadvantages are: (1) The center houses are shaded more or less, (2) side light and side ventilation can not be had, and (3) soil and other materials must be carried into the house from the end instead of being put in at side openings. The latter is a serious ob-

jection only when the houses are long and narrow.

The above remarks refer only to separate and connected houses of similar sizes. At the present time there is a difference of opinion as to the advantages of the single wide and high house over the small and lower

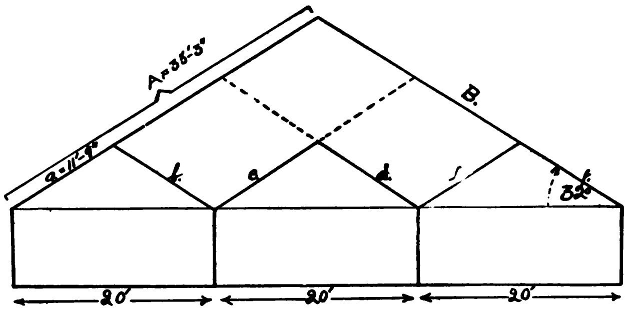

Fig. 30.—Diagram showing that the same amount of roof is required for several small, connected houses as for one large house covering the same area if the pitch is the same. a+b+c+d+e+f=A+B.

houses connected in the ridge-and-furrow system. Contrary to the prevailing notion, the same amount of glass is required by each system if the roofs are of the same slant or pitch.

The following advantages are claimed for the large, single houses: (1) They are more easily kept at an even temperature, (2) ventilation may be secured without subjecting the

plants to cold drafts, (3) they are lighter, (4) they are more easily cared for, (5) the light is more equally distributed over the whole house, (6) they quickly clear themselves of snow, (7) they contain a larger volume of air, and (8) they require fewer ventilators and less ventilating machinery.

On the other hand the following disadvantages are pointed out: (1) Their great height makes them a target for storms which in winter cause a greater radiation of heat, (2) they are less easily re-painted and re-glazed, and (3) the first cost is greater.

Notwithstanding these objections, however, the single house of moderate size (40 to 60 feet in width) seems destined to become more and more popular.

Curved-roof Houses.—Curved or curvilinear roofs are now seldom seen, except on conservatories and show houses. Their chief use is for ornamental effect. They originated in an attempt to so arrange the glass as to more perfectly intercept the direct rays of the sun, but in practice they have proved little, if any, superior to the straight roof, and the expense is considerably greater. They have never come into general use in a com-

mercial way. Curved-roof houses are made to use either curved or straight glass.

Side-hill Houses.—Mention has already been made of one of the forms of this type of house. Sometimes a modification of the

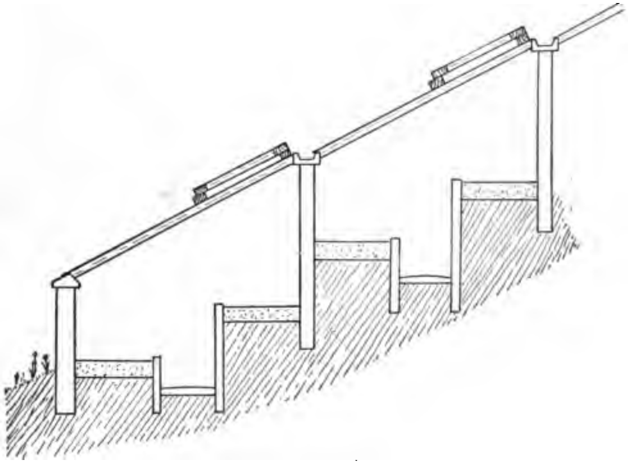

Fig. 31.—Diagram of a side-hill range

ridge-and-furrow house is utilized for side hill construction. Side-hill houses are not recommended when well drained, level land may be secured, because of the disadvantage of working at different levels.

Curved-eave Houses.—The shade caused by eave plates and gutters, the difficulty of keeping them in repair and their interference

Fig. 32.—Curved-eave and circular types of construction. Houses erected by The Pierson U-Bar Company

with the clearing from the roof of ice and snow in winter, has led to the adoption by several firms, of the curved-eave construction. For small and medium-sized houses the increase in light is very noticeable. In larger houses it is not so apparent. The expense for glass is somewhat greater on account of the curved panes required.

Circular Houses.—These belong in a class with the round barn and octagonal house—excellent in theory but impractical in use. Their first cost and the expense in maintenance places them without the range of economy as commercial houses. As ornamental houses in parks and private places, and for the growing of tall tropical plants they have their place.

CHAPTER V

STRUCTURAL MATERIAL

Practically all the material, whether it be wood or metal, which goes into the construction of a modern greenhouse, is milled or shaped at the factory. It will almost never pay the prospective builder to attempt to use material made by any but specialists in this line of work. There are several such firms in this country. Greenhouse construction, then, so far as the individual builder is concerned, becomes simply a matter of choosing the kind of material he desires to use; ordering it from a responsible manufacturer and assembling it or placing it in its proper position. Most greenhouse construction firms have certain standard or stock houses which they ship complete, even including nails, paint and putty if wanted, at a definite stated price; and they will erect them if it is desired. They will also design and build a house or range of houses to suit any given condition.

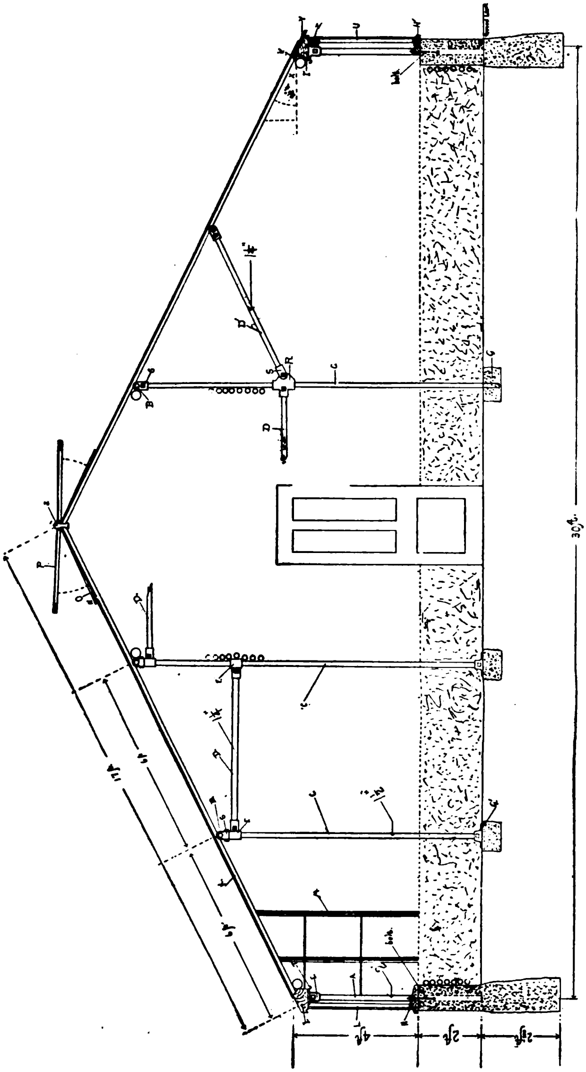

Fig. 33.—Two methods of framing a semi-iron pipe-frame greenhouse and the principal members used in greenhouse construction. A, side post; B, purlin; C, purlin post; E, F, G, R, and S, malleable iron fittings; H, glazing sill; H, sash sill; I, and Y, eave plates; J, ridge; K, sash bar; N, ventilator header; O, ventilator weather strip; P, ventilator; T, drip gutter; U, side ventilating sash; V, sash bar attachment for metal eave plate; Z, sash header

On the other hand, there is now such a variety of structural material to be had that it is quite possible, and very often desirable, for the buyer to design a house according to his own ideas or to fit his own special needs or location; select and purchase the materials and erect it with his own help to suit his special requirements.

In order to do this it is necessary to know the names and uses of the various members which go to make up the house. The principal ones are shown in Fig. 33 and are described in the following paragraphs.

Glazing-sill or Sash-sill.—This sill is bolted to the top of the wall, usually by bolts set into

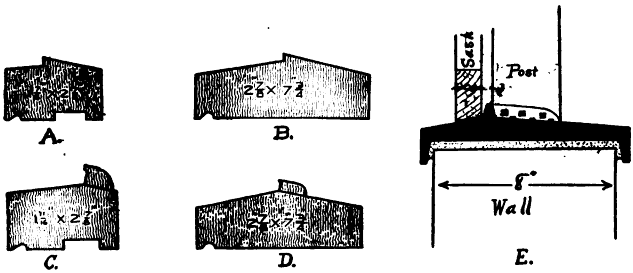

Fig. 34.—Types of sills. A, B, C, and D are wood sills; E is cast-iron

the concrete, heads down, when the wall is built. It is known as a sash-sill when the house is equipped with ventilating sash along

the side walls which close down against it; or as a glazing-sill when no side ventilating sash are used and the glass is puttied directly against it. Sills are used at the ends as well as at the sides of the house. They are of various sizes and forms, and may be of either wood or iron. The small sills are now quite popular. Grooves on the under side of the wood sills prevent the water from running back between the sill and the wall which would thus cause decay.

Eave Plate.—This plate rests upon the side posts and forms the support for the roof members. It may be of either wood or iron.

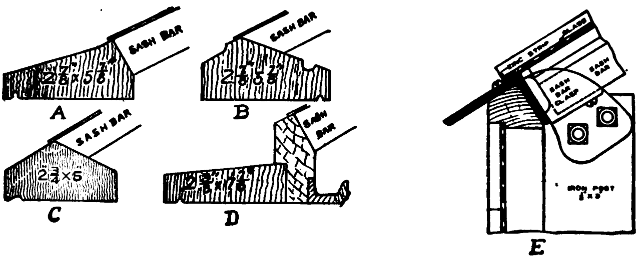

Fig. 35.—Types of eave plates. A, B, C, and D are wood; E is a metal plate

Gutter.—When it is desired to collect the water from the roof, or when houses are connected in the ridge-and-furrow system, it is necessary to use a gutter instead of an eave

plate. Iron gutters are rapidly displacing the old-fashioned wood gutters as they last longer, and because they need not be so large and hence cast less shade.

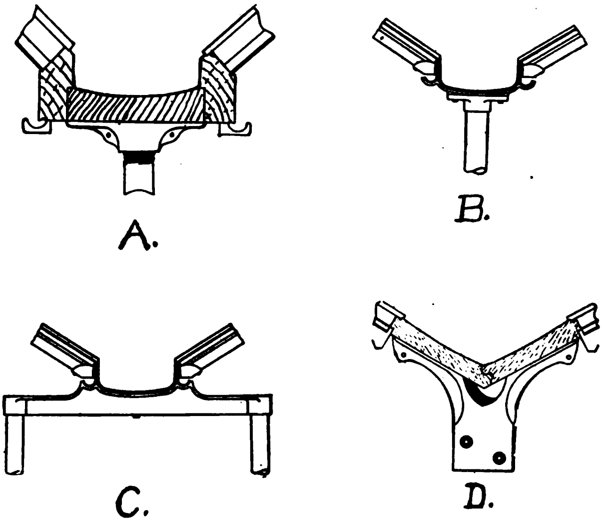

Fig. 36.—Types of gutters. A, and D are wood; B, and C are metal. C is supported by two rows of posts to allow for a walk directly underneath

When gutters are used, they have a fall of at least 4 inches for each 100 feet in length. This is accomplished by gradulally shortening the posts toward one end of the house. In other words, the side walls are higher on one end of the house than they are on the other. On very long houses the walls are

Fig. 37.—Type of gutter (a) used on curved-eave houses

sometimes so constructed that the gutter slopes from the ends each way toward the center and the water is carried away at that point. Detached houses are less commonly fitted with gutters than formerly, on account of their interference with the clearing of snow. A special form of gutter is used on curved-eave houses.

Glazing Bars.—These are bars which are spaced along the sides and ends of the house to which the glass is fastened. They are much the same as sash bars, which will be described later, except that they are usually somewhat smaller and are not provided with grooves to conduct the drip. Corner bars

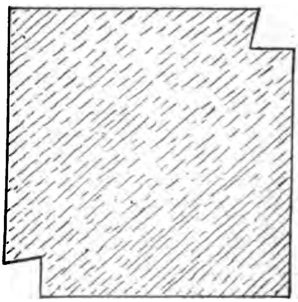

Fig. 38.—Cross section of corner bar

serve the same purpose as glazing bars, except that they are so milled that they will take the glass from both the sides and the ends of the house. One is used at each corner.

Side Posts.—These posts bear the weight and side strain of the roof. They may be of wood, gaspipe, or structural iron or steel. Their size will depend on the height of the wall and the width and construction of the house. Wood posts 4 x 4 inches, 2 or 2½-inch gaspipe, or ½ x 3-inch structural iron or steel are usually considered amply strong for most houses. The gaspipe and steel posts are usually set in concrete and masonry. It is best to set the wood posts in the same manner. Occasionally the structural steel posts are bolted to iron sills which cap a concrete or masonry wall.

Sash Bars.—The sash bars are among the most important of all the members which go to make up a greenhouse. They must be strong enough to carry the weight of the glass, yet be of such form and size as to cast the least possible shade. They are of various forms and sizes. Bars made entirely of metal are seldom satisfactory for

the following reasons: (1) They are likely to expand and contract considerably with changes in temperature, thus loosening and

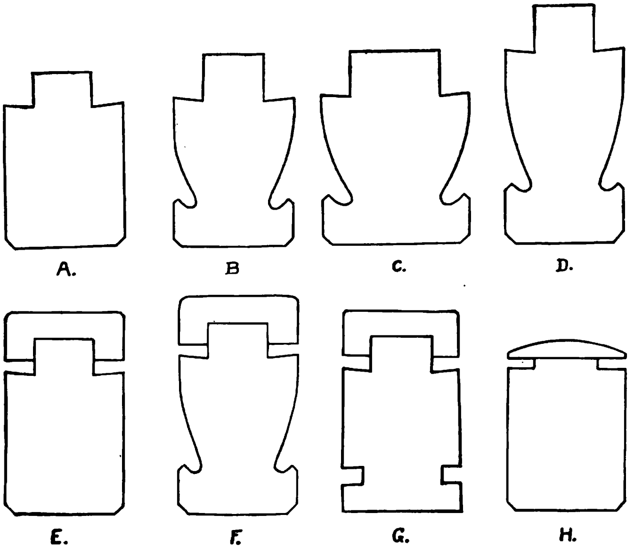

Fig. 39.—Types of wood sash-bars. E, F, and H are used for butted glazing; G is used for double glazing

often breaking the glass. (2) The extreme cold to which they are subjected on the outside, as compared with the warm temperature on the inside of the house, has a tendency to cause them to warp and thus break the glass or cause it to fit poorly. (3) As all metals are ready conductors of heat, much is lost by radiation when they are used. (4) In

cold weather they become so cold as to cause the moisture in the air inside the house to condense rapidly on them, which results in a large amount of drip. Various types of bars have been invented in an attempt to overcome these difficulties.

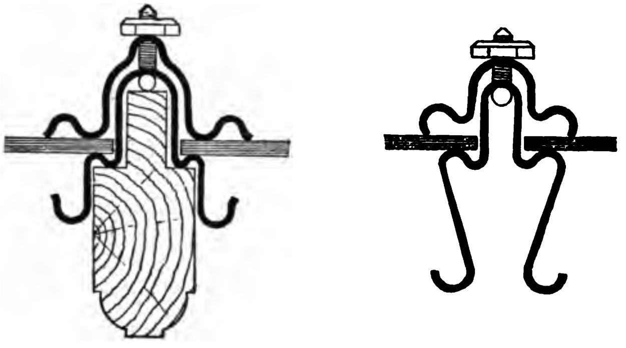

Fig. 40.—Two types of patented metal sash-bars

Wood sash bars are not good conductors of heat and condense but little moisture, but moisture from the glass finds its way to the sash bars, so that they are usually made with a groove or furrow on each side, which conducts the moisture down to the eaves. The most common size of wood sash bars is 1⅜ x 2½ inches. Larger bars are used for special purposes.

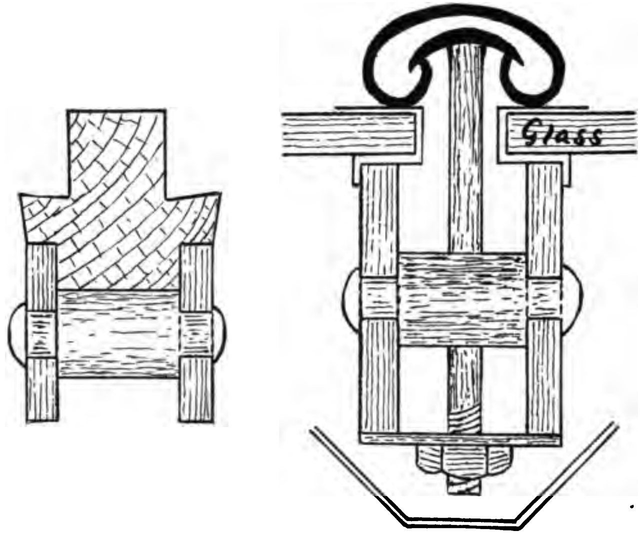

Fig. 41.—King "channel bars"

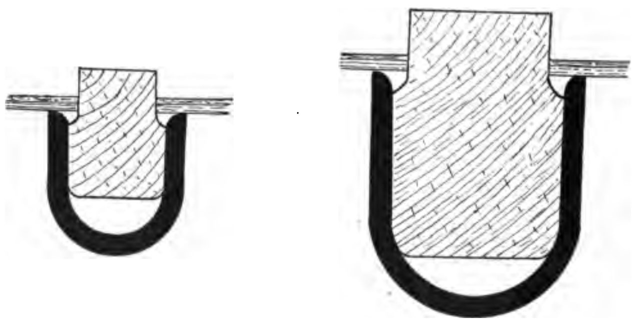

Fig. 42.—"U-Bar" type of sash-bar

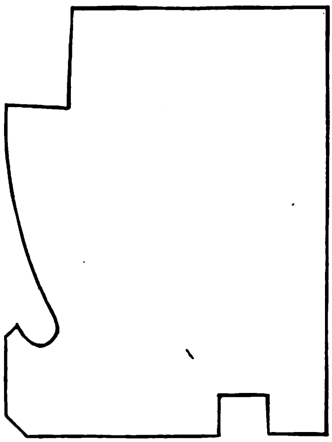

Fig. 43.—Gable rafter

Gable Bars or Gable Rafters.—Gable rafters are used at the ends of the roof and are made so as to receive both the glass of the roof and that of the end of the house. They should be large and strong enough to give rigidity to the gable.

Drip Gutter.—The purpose of the drip gutter is to carry away the water formed by condensation inside the house, which is conveyed to it by the sash bars. The pipes leading from it should empty into a cistern or sewer connection inside the house, or be

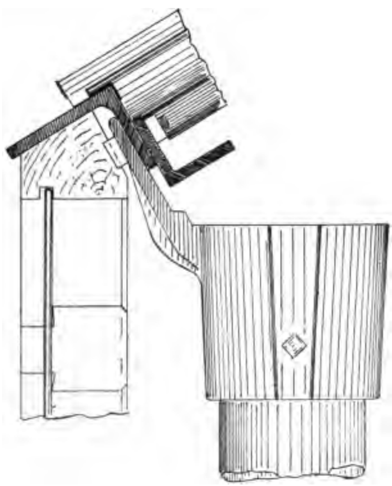

Fig. 44.—Combination eave plate and gutter

carried out below the frost line. This is necessary to prevent freezing, as the greatest drip is in the coldest weather. In some forms of construction where pipe side posts are used, they are utilized as conductors of the drip water, but the saving thus accomplished is usually more than counter-balanced by the early rusting out of the posts. Gutters are made of wood, zinc, tin and galvanized iron.

Purlins.—Since sash bars must be small to minimize the amount of shade, it is evident that on wide houses they cannot carry the weight of the glass without support. This is accomplished by means of purlins. They run lengthwise of the house, and are themselves supported by purlin posts, by purlin braces, by rafters or by some form of truss work to be described later.

When ordinary wood sash bars are used with glass 16 inches wide, the maximum distance for safety between purlins is not more than 7 feet. For example: If the sash bars are more than 7 feet long, one purlin should be used. If they are more than 14 feet long, two purlins should be used, and so on. This distance decreases as the size of the glass increases since there are fewer bars to sustain the same weight.

Purlins may be of wood, gaspipe or angle iron. Wood purlins, because of their size (1⅜ x 3 inches), cast so much shade that they are now little used. Purlins of 1¼-inch gaspipe are very satisfactory. They are fastened to each sash bar, and are supported by posts or braces every 8 feet along their

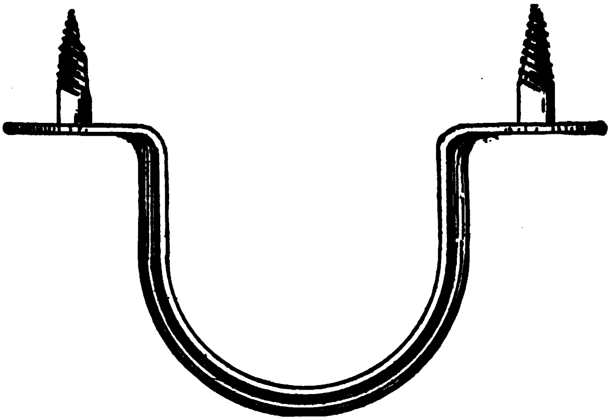

Fig. 45.—Pipe-strap for fastening sash-bars to purlins

length. A very satisfactory means of fastening them to the sash bars is by means of a U-shaped pipe-strap. This is placed under the purlin and fastened to the sash bars by means of screws.

Ridge.—The ridge furnishes a means of fastening the upper ends of the sash bars and also serves as a support for the ventilators.

It is milled from a 2 x 4, or a 2 x 6-inch timber, the size depending on the width of the house. The form varies according to the method of attaching the ventilators. (See Chapter VIII).

Ventilators.—These are fully discussed in Chapter VIII.

Ventilator Header.—This is a member upon which the lower side of the ventilator rests. It is cut and grooved at the factory so as to fit over the sash bars and to receive the edge of the glass of the roof in its lower side.

Sash Hanging Rail.—When side ventilating sash are used a special piece is sometimes placed immediately under the eave plate or gutter, to which the sash are hinged. This is known as a sash hanging rail. Sometimes the sash are hinged directly to the plate or gutter.

Weather Strip.—Because of their construction and the method of hanging, the roof ventilating sash do not fit down tightly upon the sash bars but leave wedge-shaped openings. These are closed by pieces known as weather strips.

Rafters.—Their use is now confined almost wholly to all-metal frame houses which are discussed in Chapter VI.

KINDS OF WOOD

Three kinds of wood are now being used in greenhouse construction: Cypress, cedar and California redwood. Of these the first two are preferred on account of the higher

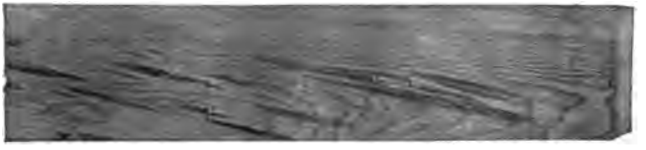

Fig. 46.—"Pecky" cypress

cost of redwood. There is little difference in the durability of cypress and cedar. If well framed, and if thoroughly painted when erected and at least once in two years thereafter, either will last a lifetime.

Pecky cypress is the heartwood from old trees. It is full of holes or "pecks" and is often too "shaky" for sash bars and other small members, but it is one of the most durable woods known. It is used chiefly for benches, and in other places where ordinary lumber decays rapidly and where great strength is not needed.

FRAMING

The woodwork of a greenhouse always begins to decay at the joints. For this reason particular attention is paid to the framing. All joints are made to fit closely, and before putting together each piece should be primed with a thin coat of lead paint. The joints

Fig. 47.—The concentric system of construction

are then given a heavy coating of thick white lead and put together while the paint is still green.

In buying greenhouse material it is always well to buy all the woodwork from one firm and to give the concern a careful description of the house, together with a drawing showing the width, height and length of the house, the pitch of the roof, size of glass to be used, etc. The firm will then send the

woodwork (if it is so directed) cut so that it may be fitted together with but little trouble. It should be specified, however, that it be well seasoned and not warped. Warped millwork, especially sash bars and glazing bars, are exceedingly difficult to put in proper position.

Some factories now build their eave plates and sash bars on the concentric principle. which does away with the necessity of cutting the ends of sash bars differently for roofs of different angles.

CHAPTER VI

FRAMEWORK—METHODS OF ERECTING

The two cardinal virtues of a good greenhouse framework are these: It must be strong and light, and it must cast but little shade. The greatest advance in greenhouse construction in the last quarter of a century has been in the framework. The old houses with their high, solid walls and heavy woodwork are dingy and dark, when compared with the modern house, 90 per cent. of which is glass, with little or no solid wall above ground. The framework of these houses casts but a fraction of the shadow produced by the old-style frame, yet it is so perfectly rigid against storms and snow that the large panes of glass are seldom broken or even loosened in their setting.

Three general classes of framework are used: (1) Wood frame, in which all members, including the posts, are of wood; (2) semi-iron frame, in which the posts, purlins and purlin posts are of pipe or structural iron,

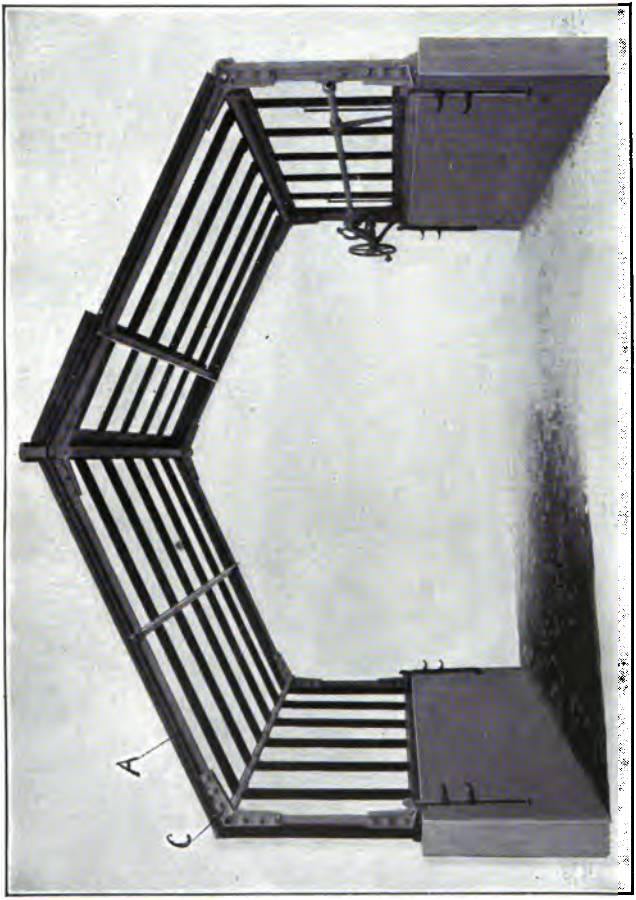

Fig. 48.—A type of all-metal, flat-rafter construction. A, rafter; C, gusset plate. (Courtesy King Construction Co.)

and (3) all-iron or all-steel frame. In wood and semi-iron construction, rafters are seldom used, the sash bars performing this function as well as their own. These forms have the advantage of being somewhat cheaper than the all-metal frame construction, and have the additional advantage that the material may be cut and fitted on the job by any experienced workman.

Wood frame houses cast more shade than semi-iron, and are less durable, especially the posts. Semi-iron houses are very durable, and for houses of medium width, are very satisfactory. Probably more houses of this type have been built during the past ten years than of all others, though the all-metal frame house is now gaining in favor. This is especially true in the East, where large houses are coming into vogue.

The all-metal frames are cut and fitted at the factory and are then shipped, knocked down, to the place of erection. Most styles of all-metal frames have rafters, which are bolted to the side posts by means of gusset plates to form bents. The bents are then placed in position and secured there by stays and purlins. Upon this framework are then bolted the wood sash bars and glazing

bars. Metal sash bars, as before mentioned, seldom prove satisfactory. The framework of such houses is practically indestructible, and when the woodwork decays it can be replaced upon the old framework.

Usually the weakest part of a greenhouse is the gable. It should be well framed and securely tied to the purlins and other parts of the framework.

METHODS OF ERECTION

Foundations and Walls.—In the old-style high, solid wall greenhouse, the wall was a source of much perplexity, especially the high north wall of the uneven span house. In modern houses, however, the solid wall is seldom higher than the top of the benches, when benches are used, or only a few inches above the surface when plants are grown on the ground. The remaining part of the side-wall is constructed of posts and glass, thus giving more light. The chief difficulty with the high, solid wall was that the extremes of temperature between the outside and inside in cold weather caused them to disintegrate rapidly. This was particularly true with masonry walls.

Modern greenhouse walls, for commercial houses, are almost always of concrete and, being low, give little trouble. Concrete blocks and hollow building tile are much used. The chief requisite is that the foundation shall reach below the frost line. The common practice is to dig a trench 12 or 15 inches wide and 3 feet deep and fill with coarse concrete to within a few inches of the surface. A form is then built of lumber to the height required and filled with concrete. When the concrete has "set," the form is taken away and the sides of the wall plastered with a cement mortar. In wet, springy soil it is often desirable to lay a row of drain tile along the outside of the wall and nearly to the bottom of the trench, to carry off the water.

Concrete walls are usually much more satisfactory than either brick or stone. They should be from 8 to 12 inches thick, according to their height and the side strain to which they are subjected. Usually 8 inches is sufficient. In wet soils when the boiler is placed below the surface, it may be necessary to waterproof the walls. For data on concrete construction see Chapter XV.

Wood Frame Houses.—These are quite satisfactory when a cheap house is wanted for a comparatively few years. The side posts, which may be of cedar or cypress, and 3 x 4 inches in size, are placed 8 feet apart in holes 3 feet deep, and extend to the height

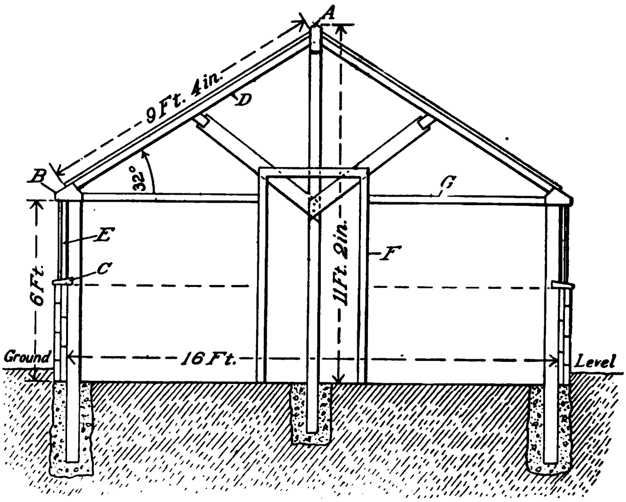

Fig. 49.—Plan for an all-wood frame greenhouse

decided upon for the side walls. They are then placed in alignment and the holes poured full of thin concrete which soon hardens. The end posts are similarly placed, except that they extend only to the height of the boarded-up portion of the wall.

The next step is to place the center posts, which are usually 2 x 3 or 2 x 4 inches in size. The height of the ridge having been determined (see Chapter III) these posts are cut long enough to allow the lower end to be set in the ground about 2 feet. They are then put in alignment and embedded in concrete the same as the side posts. The ridge is then put in place on top of these center posts, and the eave plate on top of the side posts, all joints being set in thick white lead paint.

The sash bars on a house over 12 feet in width must be supported with purlins, but it is not necessary to support them with two extra rows of posts. A perfectly safe and much more convenient way is to support them with arms or braces from the center posts. This saves valuable ground space, and the arms serve to stiffen the center posts as well. The length and position of these arms may be determined by placing a straight edge from ridge to eave plate in just the position the sash bars will occupy, and nailing the arms fast, first allowing for the thickness of the purlin. A good mechanic would have determined this before the posts were

set, and have nailed the arms in place before raising them. The amateur, however, will find it best to put them in place after the posts are up, or at least to put up a trial post and then make the others after it as a pattern.

The next step is to nail on the purlin, and then it is ready for the sash bars, which are spaced carefully so that the distance from rabbet to rabbet is about one-eight-inch greater than the width of the glass. This can best be accomplished by using a board about one-eight-inch wider than the glass, and nailing the bars so that the rabbets fit snugly against it along their whole length. The board can then be removed and used to space the next, and so on.

The side and end posts are next boarded up to the required height, using two layers of matched lumber with paper between. The bottom board, at least, must be of best quality pecky cypress to guard against decay. Glazing bars may now be fitted along the sides between the eave plate and the glazing sill, and between the glazing sill and the gable rafters. Corner bars are placed at each corner.

It will also be necessary to make a frame for the door at one end, and to reinforce the gable glazing bars with 2 x 4-inch scantling. The house is then ready for glazing, instructions for which will be found in Chapter VII.

If cypress or cedar lumber is used throughout, and if kept carefully painted, a house like the above should last for fifteen or twenty years. The most vulnerable parts are the posts, especially the portion where they enter the cement. They should be painted regularly once each year at this point. While these houses do not admit as much light as either a semi-iron or an all-iron frame they will give excellent service. A poorly built all-wood frame house is a constant expense for maintenance.

Semi-iron Frame Houses.—Two methods of framing a semi-iron frame house are shown in Fig. 33. The method shown on the left requires twice as many purlin posts as the one on the right. In each case gaspipe is used. The work of erecting differs but little from that described for wood frame houses, except that pipe working tools are required, and a little more skill is necessary. An endless variety of fittings may be had

for this style of framing, which makes the joining of the frame work comparatively easy.

If it can be procured, genuine wrought-iron pipe is best used instead of the steel pipe now commonly sold. Steel pipe rusts out

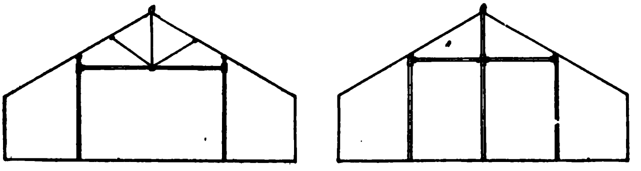

Fig. 50.—Two methods of framing a semi-iron house For others, see Fig. 33

much more quickly. In this style of house the wall is usually of concrete and may be only a few inches above the surface of the ground, or any height desired. The side posts which are usually of 2-inch pipe are put in position and stayed before the concrete is poured in, so that when the wall has set they are perfectly rigid. Adjustable brackets which fit on the top of the posts, and to which the eave plate or gutter is attached, make possible the correction of trifling variations in height.

Bolts are set, heads down, in the top of the wall while it is soft, and project upward 2 or 3 inches. These are used for fastening down

the sill, which is bored to fit over the posts and bolts and is secured with nuts. No posts are set in the end walls, but the bolts are set the same as in the side walls and are used for the same purpose. In some cases the posts are set in the ground and the side walls are constructed of two layers of matched lumber.

Fig. 51.—Structural steel post with board wall

The purlin posts and other supports are put in position much the same as in the wood frame house, except that instead of being embedded in concrete, they are sometimes provided with foot pieces and rest on small concrete piers. Split malleable iron castings may be had in almost every conceivable form for joining the frame together. These are fastened by bolts and set screws, so that it is not necessary to thread the pipe. The sash bars are fastened to the pipe purlins by means of U-shaped clips or pipe-straps, which are secured to the bars by means of screws. Purlins are usually made of one and

a quarter-inch pipe and should be supported by posts every 8 feet. Purlin posts are usually of one and a half-inch pipe and braces of one and a quarter-inch pipe.

A well-built house of this type, if well cared for, should last a lifetime.

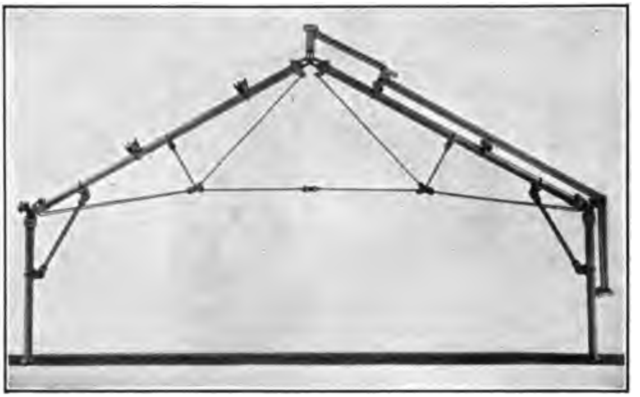

Fig. 52.—Section of truss-frame greenhouse. The frame is made of gaspipe

Semi-iron frames are also made from structural iron instead of pipe. They are just as satisfactory, but are not so easily worked, and are usually cut and fitted at the factory.

All-metal Frame Houses.—There are three types of all-metal framework: (1) Those in which the roof is supported by interior posts, much the same as in the wood or semi-iron houses. (2) Those in which the roof is sup-

ported by a truss work, thus doing away with all interior posts (sometimes known as truss-frame). (3) A combination of the above forms (known as a combination truss-frame) is used in houses so wide as to make the truss-frame impractical. This is commonly used in houses over 40 feet in width.

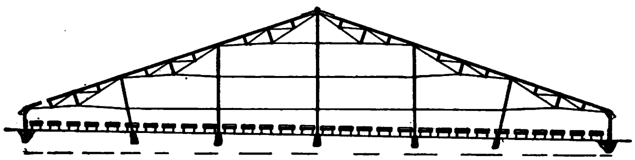

Fig. 53.—Section of combination truss-frame greenhouse, 172 feet wide

As has already been mentioned, all-metal frame houses usually have wood sash bars and glazing bars, but they are not considered as parts of the framework. In these houses the completed framework is entirely of metal, the wooden members being fastened to the frame with bolts or screws and serving only to hold the glass in place.

In many all-metal frame houses, especially when the roof is supported by inside posts, it is common to bolt an iron or steel sill to the wall and then bolt the side posts to this sill.

A method of erecting a modern combination-truss frame house, 73 feet wide and

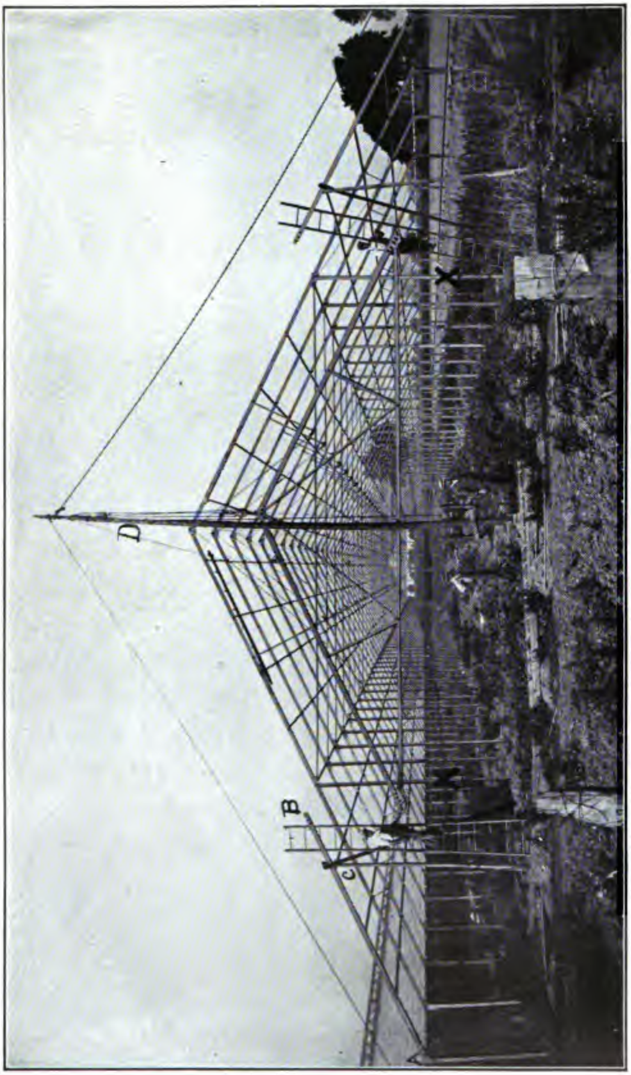

Fig. 54.—Method of erecting a large combination truss-frame house

nearly 30 feet high, to the ridge, is shown in Fig. 54. This work was done entirely by the owners and their ordinary help, without any expert superintendence and at a material saving in cost.

The method was comparatively simple. The material was first carefully distributed on the site selected, and a trench dug for the foundation. The gable trusses were then bolted together, while another gang of men began setting and guying the side posts. The trench was then filled with concrete, making the side posts rigid. Next the interior posts were put in place.

The first step in putting up the rafters was to fasten the lower ends to the tops of the side posts loosely, so that they would move easily, and then raise the other end into place by means of a pair of "shears," made of two pieces of 2 x 4-inch scantling. When these had been securely bolted in place, the gable truss, which had been previously assembled, was swung into place by means of a block and tackle, working from a boom. All that remained was to insert and tighten the bolts, put the purlins in place and move on to the next bent. The author was told by the owners of this house that it was erected

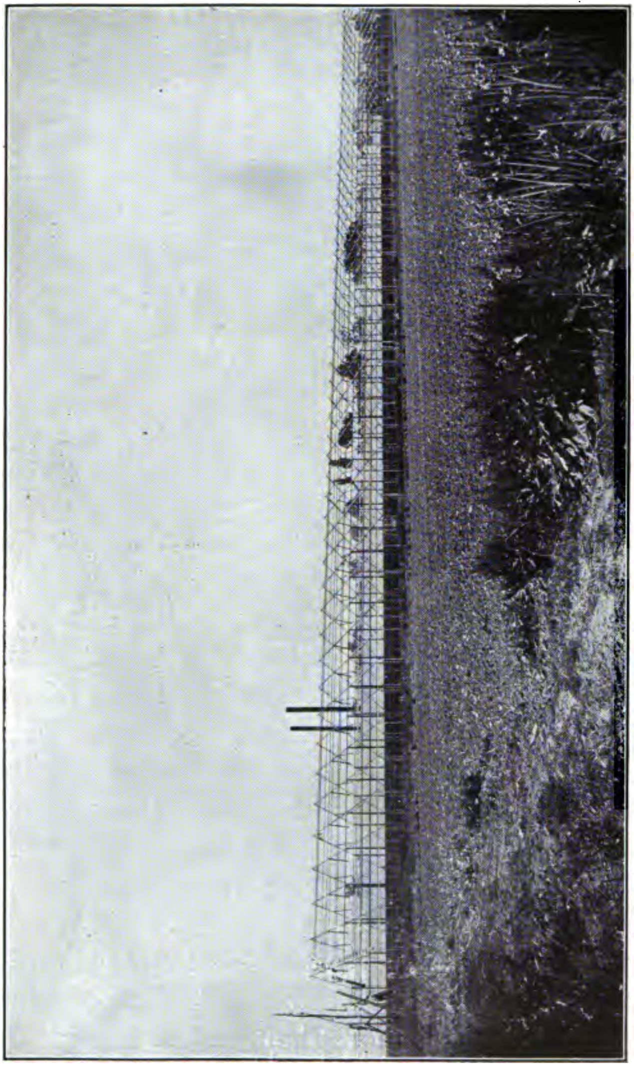

Fig. 55.—Side view of house shown in Fig. 54

with greater ease than any semi-iron house they had ever built.

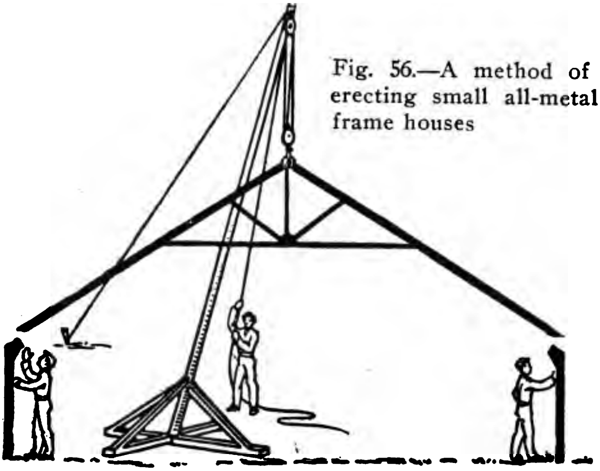

Fig. 56.—A method of erecting small all-metal frame houses

Structural steel is most largely used in truss-frame houses though gaspipe is now quite popular. It is claimed for gaspipe that it costs less than structural steel and that it casts less shade. Some objection has been urged against houses constructed of gaspipe on account of a lack of rigidity, but as now constructed they give very satisfactory service. Houses of this type are regularly supplied by manufacturers up to 54 feet in width, without center supporting posts. It is probably safest to have two rows of supporting posts in houses more than 40 feet in width.

CHAPTER VII

GLAZING AND PAINTING

Greenhouse glazing is an art in itself. Most construction firms employ professional glazers. It is, however, an art that may be readily acquired. Many owners do their own glazing when occasion requires, or have it done by their ordinary help. The method of glazing greenhouse roofs is not the same as that used in glazing window sash. When glazers from glazers' shops or hardware stores are employed, precaution should be taken to see that they understand the difference.

Glass.—The glass commonly used in greenhouse glazing is clear, white, sheet or window-glass of either A or B grade. Glass with a pronounced green or bluish cast is to be avoided, as it obstructs a large part of the heat, light and chemical energy of the sun's rays.

Clear, white window-glass ordinarily absorbs about 30 per cent. of these rays; green,

from 40 to 50 per cent.; and blue, from 50 to 80 per cent.

Glass known as A, or first grade, is blown from the top of the retort and is of better quality than the B, or second grade, which may contain some foreign matter or settlings. Some of the less regular panes from the first blowing and those containing small air bubbles are also placed in the B grade. When it is essential that the greatest possible amount of light be had and tight glazing is necessary, A grade is used.

In most commercial constructions B grade will give satisfactory results. Poorer grades are not satisfactory for greenhouse work. The cost of B grade is about 85 per cent. of the price of A grade. Both A and B grades may be had in two weights or thicknesses, known as single-thick and double-thick. Single-thick runs about 12 panes to the inch and weighs from 19 to 21 ounces per square foot. Double-thick runs about 8 panes to the inch and weighs from 26 to 29 ounces per square foot. Double-thick is almost always used when the panes are more than 8 x 10 inches in size. It obstructs but little more light and is much more durable, especially against hail.

The price of single-thick is from 60 to 70 per cent. of the cost of double-thick. American window-glass is the best that can be procured. The price varies greatly from year to year, probably more than does the price of any other standard building material.

American-made glass is packed in boxes of about 50 square feet each. Foreign glass comes in boxes of approximately 100 square feet each. The number of lights per box of the various sizes of American-made glass is shown in the following table:

LIGHTS PER BOX ACCORDING TO SIZE

Size	Lights per box	Size	Lights per box
7x 9	114	14x16	32
8x10	90	14x18	29
8x12	75	16x20	23
10x12	60	16x24	19
10x14	51	18x18	22
12x12	50	18x20	20
20x14	43	18x24	17
12x16	38	20x20	18
14x14	37	20x24	15

Plate glass is seldom used in commercial greenhouses, as its cost is prohibitive. It is but little better than A grade window-glass for this purpose. In conservatories where strength is more important than transparency, fluted or corrugated glass, or glass in-

to which wire netting has been blown is sometimes used. Ground or frosted glass is occasionally used in palm-houses or ferneries, where a soft, subdued light is desired. This effect is more commonly obtained by painting or whitewashing the clear glass and varying the thickness of the coating according to the season of the year.

Size of Glass.—The size of the glass varies according to the purpose for which the house is to be used, and the taste and personal preference of the owner. Where extreme lightness is wanted, large panes are used thus diminishing the number of sash bars. There is, however, a practical limit to the size. Glass increases rapidly in price as the size increases, and the large panes break more easily. Moreover, the size of the sash bars must be increased to carry the extra weight, and every increase in their size means more shade.

Of 136 practical growers consulted on this point, 108, or nearly 80 per cent., favored either 16 x 20 or 16 x 24-inch glass with the longer edge parallel to the sash bar. That is, the great majority preferred to have the sash bars spaced about 16 inches apart.

About 3 per cent. favored 16 x 20-inch glass with the shorter edge parallel to the sash bars, the bars in this case being 20 inches apart. Glass 16 x 20 inches is undoubtedly the most popular size.

Methods of Glazing.—Practically all methods of glazing make use of putty to seal the glass in place and to form an air and water-tight joint. An exception is made when some forms of metal bars are used. With these, felt, candle wicking or some similar material is usually employed, and the glass is pressed firmly against it and kept in place by bolts or clamps. Sometimes a lead facing is used and the glass is clamped against this facing.

The great majority of houses are constructed with wood sash bars or bars having wood cores with which putty is supposed to be used. With these there are two common methods of setting the glass. It may be lapped or butted.

Lapped Glazing.—In lapped glazing the lowermost panes in each run are laid flat against the bottom of the grooves in the sash bar. Each succeeding pane is then laid so that its lower edge laps over the upper

edge of the pane below it, in much the same way that shingles are lapped, except that the lap is much narrower. From one-eighth to three-eighth inches are allowed for lapping, the width of the lap depending somewhat on the size of the glass and the rigidity of the house and roof. It should be as narrow as possible, for little light passes through the lapped part of the roof.

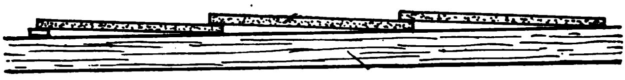

Fig. 57.—Lapped glazing

Butted Glazing.—In butted glazing all panes lie flat against the bottom of the grooves in the sash bars, and the lower edge of each glass rests directly against the upper edge of the one below. This form of glazing eliminates the lap, but it is more difficult to secure a tight roof than when the glass is lapped. Roofs having a pitch of less than 30 degrees are likely to leak badly when the glass is butted.

In this form of glazing the putty is sometimes omitted, and the glass is held in place by wood caps which fit over the rabbets. When it is desired to make an especially tight

roof, the upper and lower edges of the panes are sometimes dipped in a shallow tray containing thick paint. They are laid while the paint is soft, and in hardening this forms a tight, waterproof joint. Zinc glazing strips, bent in the form of a letter *Z* were at one time quite extensively used between the panes to make a tight joint. They are still used to some extent between the panes on side and end walls.

Several advantages are claimed for butted glazing: (1) Less glass is likely to be broken by accidents, for if only one pane is hit, it only will be broken; while if the panes are lapped, the one immediately below is often cracked. (2) Less glass is broken by the action of frosts, as there are no laps in which moisture can collect and freeze. (3) The roof is lighter, as there are no laps to obstruct the sunlight.

The chief disadvantage, aside from leakage, is the difficulty in repairing the roof when a glass is broken, for the pane must be cut to fit tightly. In cold, stormy weather, this is a slow and tedious process.

Butted glazing is much less used than formerly among practical growers, which is proof that, in general, it is not so well suited

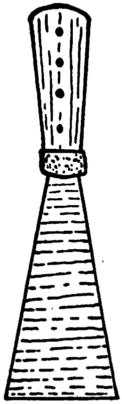

Fig. 58.—Putty knife

for glazing roofs as is lapped glazing. More than 90 per cent. of the growers interviewed on this subject preferred lapped glass roofs. On side and end walls, glass is quite commonly butted with good results.

Putty.—Putty is a pliable substance used in setting glass. The principal ingredients are whiting and linseed oil, and its chief virtues are that it is easily worked and applied, and that it does not shrink on drying, thus making a water-tight seal. For greenhouse use, putty as bought in the general market should be mixed with pure white lead at the rate of one part of lead to five of putty. This will stick to the bars and glass much better than will ordinary putty.

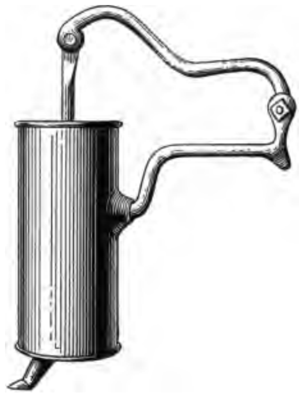

Fig. 59.—Machine for distributing putty

Putty purchased from dealers in greenhouse supplies will not need the addition of lead. It should be worked as soft as it can be handled in order that it may be easily forced into all cracks and crevices. It is applied with a putty knife or with a putty machine. The putty machine distributes the putty rather more rapidly than can be done by hand, but it is necessary to use a putty knife in conjunction with it.

Setting the Glass.—The basic difference between glazing greenhouse roofs and glazing ordinary window-sash is in the method of applying the putty. In glazing window-sash, the putty is placed on the outside. In greenhouse glazing the putty is placed in the

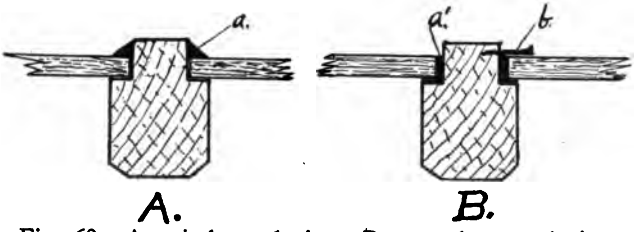

Fig. 60.—A, window glazing; B, greenhouse glazing
The putty is shown at a and b

grooves in the bars and the glass is forced into it. That which oozes up around the edges is scraped off and used again. By this method, little putty is exposed to the air, but

the glass is sealed by a thin film underneath and along the sides of each pane. This method has been developed because experience has shown that on roofs putty soon checks and crumbles away when exposed to the weather as in window glazing.

When glass is lapped, the following method is used. First, the sash bars should have been so placed that the space left for the glass is about one-eighth of an inch wider than the glass. This provides room for the "side putty." (For method of spacing see page 87). Sash bars are usually primed when received from the factory. They are given another coat of paint after they are put in place and are then ready for glazing.

Glazing is started at the bottom of the run. A line of soft putty is first placed in the rabbets and a pane of glass forced firmly into it until it is imbedded against the bar. A groove is usually provided in the plate to receive the lower edge of this glass to prevent it from sliding down, but if there is no such groove, three or four brads or glazing points are driven for the lower edge to rest against.

The excess putty is then removed and the next glass forced firmly into place, so that its lower edge laps over and rests firmly on

the top of the first, and its upper edge rests on the sash bar. This is fastened at the bottom with brads or glazing points to prevent its sliding down. The remaining panes of the run may then be placed in the same manner, special care being taken to secure the uppermost firmly in place with glazing points. This is necessary because it has no glass above it to hold it in place, and because it acts somewhat as a key to keep the others in position.

It is best to finish each run from bottom to top before starting on a new run, in order that the putty may cement into a continuous mass. On high and wide roofs, however, it is sometimes advisable to glaze the lower half of the roof, then move the scaffolding and glaze the remainder.

How to Estimate Putty.—The amount of putty necessary to glaze a roof may be estimated as follows: A pound of putty, when applied by an experienced workman, will reach about 15 feet along one side of a run of glass or about 7½ feet along both sides. To estimate the amount of putty, therefore, multiply the length of the run in feet by the number of runs and divide by 7½. This will give the number of pounds required. The

amount required for the sides and gable may be found in the same way. An inexperienced workman will use somewhat more than this amount as there will be more waste.

In glazing by the "butted glass" method, putty may or may not be used. When it is used, the method is very similar to that described above, except that much less is required, as the panes are crowded down to the bottom of the rabbet along their whole length instead of only at their upper end. Sometimes in glazing by this method no putty is used until after the glass is laid, and then a small quantity of liquid putty is forced down along the sides of the glass with a putty bulb. Usually when the glass is butted, the bars are surmounted by wood caps. In this system special care must be taken to fasten the lower pane, as the sliding weight of the entire run rests against it.

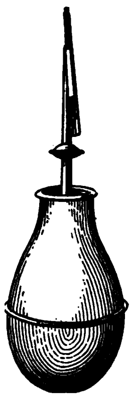

Fig. 61. — Putty bulb

Glazing Points.—Glazing points are used to hold the glass in place. They may be had in several forms and sizes. A good glazing point is easily driven, does not split

the wood, offers as little obstruction as possible to the brush in painting and does not rust. Small sizes suitable for glazing window-sash in which the putty is placed on the outside are too small for greenhouse glazing. Zinc points of various forms have been frequently used because of their freedom from rust. The triangular point is probably the most popular of the zinc points, and

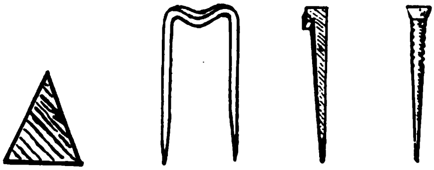

Fig. 62.—Types of glazing points

is quite commonly used in window glazing. It is not well suited to greenhouse glazing on account of the difficulty of fastening the panes of glass with it so that they will not slide down the roof.

Probably the most used point in greenhouse glazing is the double-pointed staple. This is easily driven and when galvanized is not subject to rust. The best form of this type of staple is bent to an angle in the center, so as to fit over and hold the lower edge

of the pane from slipping lengthwise, as well as to hold it down in place.

In lapped glazing only two double points are used for each pane, that is, one at each

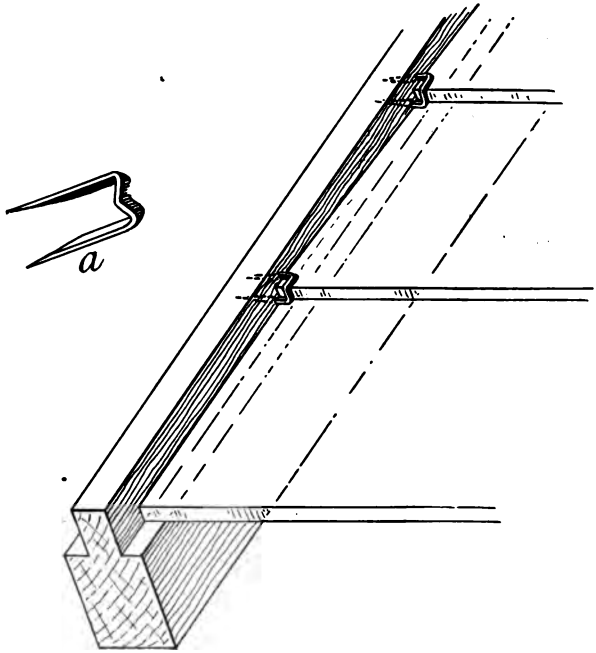

Fig. 63.—Glazing with double glazing points

lower corner. The upper edge is kept in place by the bottom of the pane above it. Additional points are required for the lowermost and topmost panes in each run, and as some will be lost and destroyed, it is well to

figure on three points for each pane. An average of five of the small single points will be required for each pane.

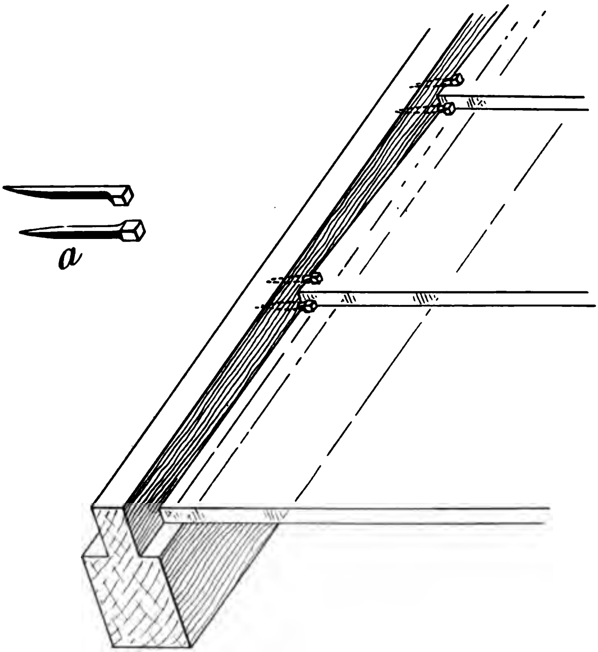

Fig. 64.—Glazing with single glazing points

Precautions.—All sheet glass is slightly curved, a condition caused by the process of manufacture. When seconds or B grade glass is used, it will sometimes be found that the panes will be so much curved as to make

it difficult to lay a tight roof. If this trouble is experienced, it will be of advantage to sort the glass and lay out each run on a smooth floor, placing the panes having a similar degree of curvature in the same run. By doing this a tighter and more satisfactory roof can be laid.

Theoretically, the glass will resist more pressure if it is placed so that the curve will be up, that is, so that it will present a convex surface to the weather. If, on the other hand, it is placed so as to present a concave surface to the weather, the water will have a tendency to flow away from the sash bars and putty to the center of the runs. In actual practice, these are relatively unimportant considerations, but all glass in the same run should have approximately the same curvature.

Liquid Putty.—This is sometimes used for sealing cracks in old glazing or in glazing by the "butted" method. It may be made as follows: Take equal parts by measure of white lead, putty and boiled linseed oil. First, mix the putty and oil thoroughly and then add the lead. If it becomes too thick, thin with turpentine.

Substitutes for Glass.—On hot beds and coldframes and sometimes on temporary greenhouses, some transparent material other than glass is used. The reason for this is that glass is both expensive and heavy to handle. The most common substitutes are cloth and paper treated so as to make them waterproof and semi-transparent. Sometimes a firm but lightweight white cotton cloth is used with no treatment, but it does not admit light enough to permit satisfactory growth of plants for any length of time.

Paper can seldom be used for more than one year. Cloth may, with care, be used for several seasons. The best results are secured by stretching the cloth or paper on rigid frames or sash on which wires have been drawn tightly across at frequent intervals to serve as supports. The author has had good success by simply painting the cloth or paper, after stretching it over the frames, with pure, light, boiled linseed oil. Bailey, in the "Farm and Garden Rule Book," gives the following recipes:

(1) Paste stout, but thin Manilla wrapping-paper on the frames. Dry in a warm place and then wipe the paper with a damp sponge to cause it to stretch evenly. Dry

again and then apply boiled linseed oil to both sides of the paper and dry again in a warm place.

(2) Dissolve 1¾ pounds of soap in a quart of water; in another quart dissolve 1½ ounces of gum arabic and 5 ounces of glue. Mix the two liquids, warm, and soak the paper, hanging it up to dry. Used mostly for paper.

(3) Take 3 pints pure linseed oil, 1 ounce sugar of lead, 4 ounces of white resin. Grind, and mix the sugar of lead in a little oil, then add the other materials and heat in a kettle. Apply hot with brush. Used for muslin.

PAINTING

Probably few other structures require as careful or as frequent painting as do greenhouses. This is due: First, to the moist condition of the air in the house, which favors the decay of the wood; and second, to the difference in temperature between the outside and inside of the house, which often causes excessive contraction and expansion of the structural material. It is especially important that all joints in the framework be thoroughly coated when they are put together, and that they be well painted in order to prevent

moisture from entering. As a rule, greenhouses should be painted one coat both inside and outside every second year, and inside portions which are especially exposed to dampness and shade should be painted every year, care being taken to see that they are perfectly dry when painted. Nothing has yet been found which will excel pure white lead and oil with a turpentine dryer for this purpose.*

For the outside the intense white may be softened by the addition of a little lampblack or other coloring material, but for the inside, colors are avoided, as they have a tendency to absorb light. Pure white is undoubtedly best for interior painting.

Greenhouse woodwork when received from the factory has usually been given a priming coat. By special arrangement it is often possible to have it treated in a bath of hot linseed oil or creosote. The latter will make it

*On this point commercial greenhouse builders do not agree. One of the largest firms in the country uses a paint containing 10 per cent. of French zinc and finds it the most satisfactory paint they have ever used. Another well-known firm after experimenting with lead and zinc in varying proportions has gone back to pure lead. The tendency of zinc paints is to crack and peel, and of pure lead paints to become chalky.

almost proof against decay, but since the joints must be coated with a thick paint when the house is erected, and as the woodwork is preferably white in order to make the house as light as possible, the extra expense involved is hardly warranted. Creosote also has a somewhat poisonous effect on some greenhouse plants.

If the woodwork has not been primed when received, it is preferably so treated before it is erected. Either pure, thin linseed oil, or a mixture of oil and yellow ochre is used for this purpose. As soon as erected, the whole framework is painted inside and out before glazing. After glazing another coat is applied. Because of the frequent painting necessary, it is seldom advisable at the time of erection, to apply more than two coats in addition to the priming coat.

Paints for Iron Work.—Ordinary paints which are used for wood may also be used on most unpolished metals. The oxidization of iron and steel, however, is likely to stain white paint, unless these metals are first given a coating to prevent it. A good paint for this purpose may be made by melting together three parts of lard and one part of powdered resin. This is brushed on in a thin

layer while hot. As soon as it is dry, ordinary white lead paint may be applied with little danger of its becoming discolored. Shellac may also be used for the same purpose.

Hot water and steam pipes cannot well be painted with lead and oil paints on account of the action of the heat. One of the most satisfactory treatments for heating pipes is to paint them with the so-called "aluminum" radiator paint. This is light in color but rather expensive. Paints which dry with a glazed surface are said to interfere with the radiating properties of heating pipes. A dull drying black paint sometimes recommended for this purpose is a mixture of lampblack and turpentine, to which linseed oil is added not to exceed a fourth of the bulk of the mixture.

Amount of Paint Required.—This varies according to the kind and condition of the surface to be painted, and to some extent with the kind of paint used. Painters usually figure that a gallon of mixed paint will cover 250 to 300 square feet of white pine or cypress the first coat, and 350 to 400 square feet the second coat.

A general rule for determining the amount required is as follows: Divide the number of square feet of surface to be painted by 200, the result will be the number of gallons of liquid paint required to give two coats.

Another is: Divide the number of square feet by 18. The result is the number of pounds of pure, ground, white lead necessary for three coats.

Shading.—During the summer the heat becomes so intense in a greenhouse that some shade must be given if plants are to be grown satisfactorily. This may be accomplished by the use of muslin curtains in the inside of the house or by lath screens laid upon the roof. The most common method in commercial houses is to apply some kind of a coating to the outside of the glass which will be washed off by the late fall rains. Some form of whitewash is most satisfactory.

The author prefers a wash made of freshly-slaked stone lime and water, to which is added one part of common salt to four parts of lime. The salt is added after the lime is slaked. This is then strained and applied with a spray pump. It is usually necessary to apply this two and often three times dur-

ing the summer, but it comes off readily through the action of the fall rains and frosts and seldom requires the use of the scrub brush.

Another paint sometimes used is composed of white lead and gasoline, just enough lead being used to make a milk-colored liquid. This may be applied with a brush or with a spray pump. It adheres much better than the wash mentioned above, but is open to the objection that it is sometimes necessary to do considerable hand work to remove it in the fall.

A third wash sometimes recommended is made as follows: Slake a half bushel of stone lime. Strain and add a brine made of one peck of salt in enough warm water to fully dissolve it. Then add three pounds of rice flour, and boil to a paste. Then add a half pound of whiting and one pound of glue dissolved in warm water. Mix thoroughly and let stand for a few days, thin with water, and apply. This is the whitewash commonly used for painting fences and buildings and is very adhesive. For greenhouses it is applied in a very thin coat.

Brackets.—In glazing and painting the

outside of a roof, a common means of support for the workman is a plank supported by brackets resting on the sash bars or on every other sash bar.

Glazing Ladder.—Another device used more in painting than in glazing is a ladder

Fig. 65.—Glazing ladder used in glazing and painting

made by nailing cleats on one side of a plank for foot holds, and on the other side longer cleats so that they will rest across at least two sash bars and thus distribute the weight. The ladder is held in place by hooks which reach over the ridge.

CHAPTER VIII

VENTILATION AND VENTILATING MACHINERY

Greenhouse ventilation has not yet been worked out with the same care and precision as has the ventilation of dwellings, public buildings, or even barns for the use of live stock. On the other hand, greenhouses are seldom or never built without some special attention being given to the question of ventilation, whereas, dwellings and even public buildings are often erected without any reference whatever to this important subject.

This anomaly may be partly explained by the following facts: (1) The transpiration of plants is not so well understood nor is it so easily measured as is the transpiration of animals. (2) Windows are necessary in dwellings and public buildings to admit light and they may be utilized, when necessary, to provide ventilation. (3) In greenhouses, ventilation is not only provided for the purpose of

maintaining a supply of fresh air, but is utilized as a method of controlling temperature and humidity. (4) Greenhouses, because of their transparent roofs, are much more liable to sudden or violent changes in temperature (especially in days of alternate clouds and sunshine) than are dwellings, and the necessity for ventilation in order to equalize the temperature is evident. (5) Greenhouse plants are, as a rule, particularly sensitive to cold drafts, and ventilation cannot be left to the indiscriminate opening of doors.

Systems of Greenhouse Ventilation.—There can hardly be said to be any well defined systems of greenhouse ventilation, as compared with the so-called systems of ventilation for public buildings. Greenhouse ventilation rests on the principle that warm air has a tendency to rise, and since the air within the greenhouse is considerably warmer than that outside, during both summer and winter, the question of changing the air presents no serious problem. It is only necessary to provide a means for the warm air to escape. The cooler air from the outside easily finds its way into the house

through the numerous small openings between the panes of glass.

Side Ventilation.—Side ventilation is of little service, except during the summer months, as the opening of these ventilators in winter would expose the plants to a direct

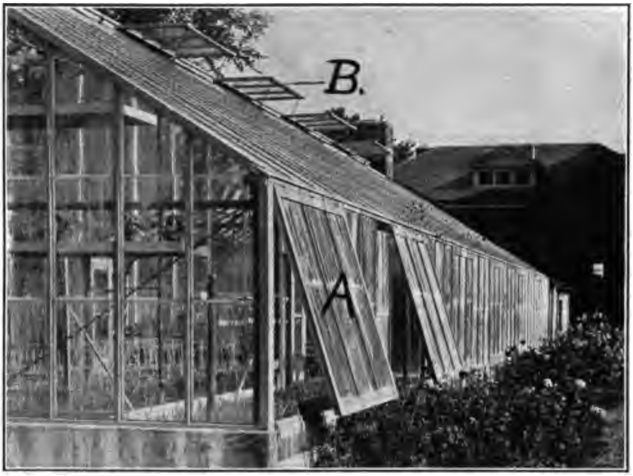

Fig. 66.—Greenhouse showing A, side ventilators; B, overhead or roof ventilators

current of cold air which would prove fatal. Side ventilating sash are usually hinged at the top and open outward and upward. Probably less than 50 per cent. of the commercial houses in the country are equipped with side ventilation, though it is often con-

venient in spring and summer. An ingenious method is sometimes employed in conservatories whereby the air is taken in from below the benches and is warmed by passing over the heating pipes. Thus the danger of injury to the plants is greatly lessened. There is no evidence to show that there is any special benefit to be derived from these ventilators (Fig. 67).

Overhead Ventilation.—During the winter practically all the ventilation of greenhouses is accomplished by means of overhead ventilators set in the roof at or near the ridge. These ventilators are in the form of sash hinged on the outside, and may be closed down tightly over the sash bars or opened to any degree desired. As the warm air naturally rises, the opening of these ventilators allows the warmest air of the house to escape, and fresh cool air to filter in through the crevices between panes of glass without causing excessive drafts.

Experience shows that these ventilators need to be relatively narrow and practically continuous along the whole length of the house, rather than intermittent, as the presence of occasional large openings is more

Fig. 67.—Method of under-bench ventilation

likely to cause drafts of cold air. They are preferably glazed with glass of the same width as used for the roof and they should be placed so that the bars of the sash will be directly over the sash bars.

Size of Ventilators.—No definite rule can be given as to the size of ventilators, as so much depends on the location and arrangement of the house, the kind of plants to be grown, etc. Experience has shown that where the ventilators are continuous along the entire length on both sides of the roof, the following sizes are sufficient.

Size of house	Width of ventilating sash
Up to 40 feet wide	24 inches
Above 40 feet wide	30 inches

This is the rule followed by most greenhouse builders.

Methods of Hanging Sash.—Ventilating sash may be hung so as to open either at the top or bottom; that is, they may be hinged at the lower side so as to open out and away from the ridge, or they may be hinged at the ridge so as to open upward from the lower side. Both methods have their advantages and disadvantages. Sash opening at the ridge have the advantage that the air will

escape more rapidly when the ventilators are opened, as there is but little obstruction and the opening is at the highest part of the house. There is also less tendency, when ventilators are used on one side of

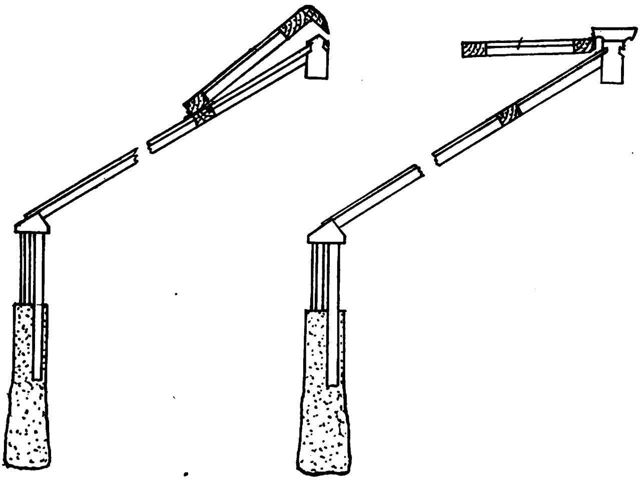

Fig. 68.—Two methods of hanging ventilator sash

the roof only, for unfavorable winds to blow directly into the house.

The practical disadvantages of this method of hanging is that the ventilator sash are more likely to be torn off by severe storms than when hinged at the top, and also that it is more difficult to prevent leakage at the ridge. The prevailing tendency is to

hinge the sash at the ridge and in houses 30 feet wide or more to provide ventilators on both sides of the roof.

Operating Machinery.—Since the ventilating sash are placed at the highest part of the house, and as it is necessary to change the size of the opening several times a day, it is obvious that it is highly desirable that some method be provided by which they may all be opened and closed from some point convenient for the operator. This is accomplished by means of various types of sash-operating machiney.

The essential features on which most types of ventilating machinery depend are as follows: (1) A horizontal shaft firmly fastened near the line of ventilating sash; (2) a system of gearing, by which power applied at a point convenient to the operator may be transmitted to and rotate this shaft; (3) arms or levers attached to the shaft and also to the sash, and so arranged that the sash are raised or lowered when the shaft is rotated.

Shafting.—The shafting generally used is one inch or one and a fourth inch gaspipe. The lengths are either riveted or clamped

together by special couplings so that the shaft will be perfectly rigid. A method sometimes used is to screw the lengths of pipe into an ordinary sleeve coupling as far as they will go; drill a hole through each end of the coupling and pipe, and rivet all together with tight-fitting rivets. This method is less satisfactory, however, than

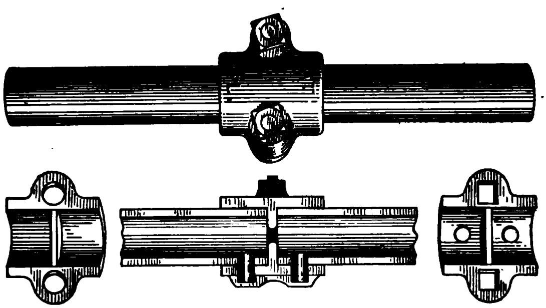

Fig. 69.—Malleable iron shaft couplings

the use of split malleable iron castings several forms of which are to be had. These castings are longer and stronger than the usual sleeve coupling and they thus have a firmer grasp on the pipe.

They usually have pins or lugs cast in the inside which fit into holes drilled in the pipe at the proper positions, and the two parts are clamped tightly in place by means of bolts. A special advantage of this meth-

od of coupling is that the shafting may be put up in sections and clamped together after being put in place. Square or round, solid shafting is sometimes used, but it has less torsional or twisting strength, weight for weight, than does good wrought-iron or steel pipe. Wrought pipe comes in two weights, standard and extra heavy. It is safe to use the different sizes and strengths as follows: Shafts up to 50 feet in length, 1 inch standard strength; shafts up to 75 feet in length, 40 feet of 1 inch extra heavy, and 35 feet standard strength; shafts up to 125 feet in length, 1¼ inch all extra heavy.

Shaft Hangers.—The shafting is held in place by means of hangers. These hangers

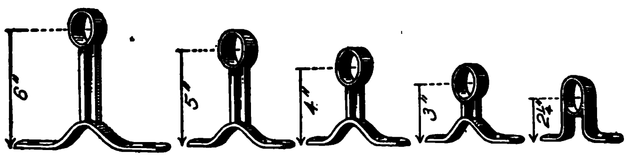

Fig. 70.—Shaft hangers

may be fastened to the rafters, to the sash bars or to the supporting posts. In iron frame houses it is customary to hang overhead shafting from the rafters and the shafting for the side ventilators from the side posts, using a hanger for each rafter or post.

When the shafting is hung from the sash bars a hanger is attached to every second or third bar, usually to every second.

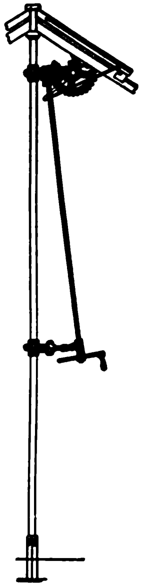

Fig. 71.—Open column ventilator gearing

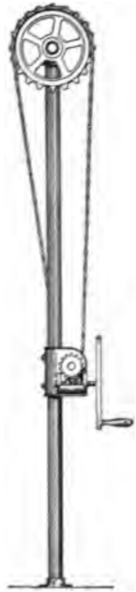

Fig. 72.—Open column chain operated ventilator gearing

Gearing.—Generally speaking, there are three types of gearing utilized for operating overhead ventilator shafting. These are: (1) The column gear, of which there are many different forms; (2) the chain-oper-

ated gear; and (3) the rack and pinion gear.

In the column gear a post or column supports the gearing and the wheel to which the power is applied. One form of column gear is known as an open column gear, because the drive rod is not inclosed in the column and there is no housing about the gearing. In another open column gear type a chain is used to transmit the power. In the closed column types all gearing is inclosed and runs in oil, much the same as in the transmission case of an automobile. This insures freedom from noise and ease of operation.

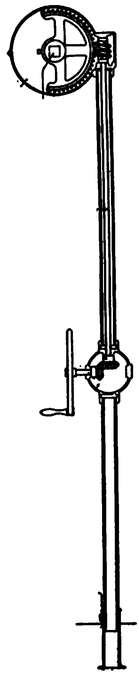

Fig. 73.—Closed column ventilator gearing

In the chain type no columns are required, a feature much prized by growers. By this system practically all the ventilators in a house may be operated from one point, as the chains may be run almost anywhere in the house by the use of pulleys. The absence of columns means less shade.

The rack and pinion type differs from the two general types mentioned above, not so much in the method of applying the power

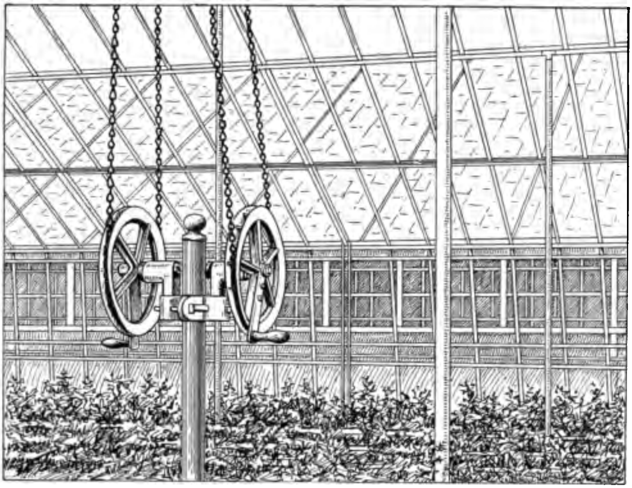

Fig. 74.—Chain system of operating ventilators. No columns used

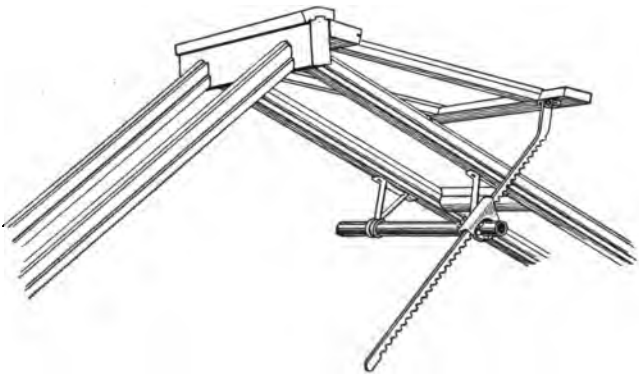

Fig. 75.—Rack-and-pinion system of operating ventilators

to the shaft as in the method of actually opening the ventilators. The chief advantage of this system lies in the fact that there is less torsional or twisting strain on the shafting than when the usual method is employed, and they are more powerful. The chief disadvantage is that provision must be made for giving the shaft several revolutions, while a half or two-thirds revolution is usually sufficient with the more common forms.

Some practical growers claim that the rack and pinion device is very subject to wear and is a frequent cause of trouble. This is more especially true of the older forms of this type. The fact that they are not generally used would seem to indicate that practical growers as a rule are not yet convinced of their superiority, though they are now being installed in some large houses where it is necessary to operate long runs.

Quite frequently the hand wheel and gearing are fastened to the rafters or purlin posts and no extra columns are required.

Side Ventilating Machinery.—The essential features of side operating machinery are the same as for overhead ventilators. When there are side benches a shaft is

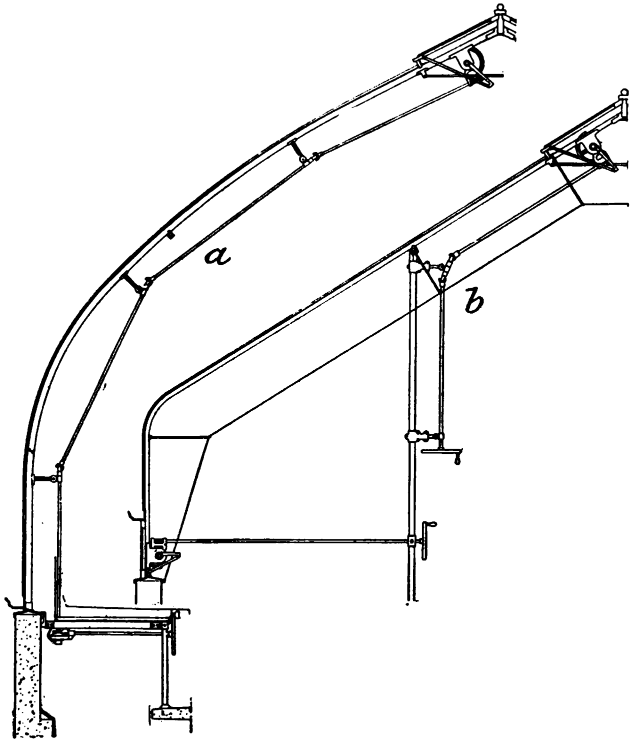

Fig. 76.—Ventilators (a and b) operated by means of rods with universal joints attached to posts and rafters. No extra columns are necessary.

usually used and the hand wheel placed at a convenient position for the operator. When there are no benches along the sides a compact device is advisable in order to take up as little room as possible (Fig. 78).

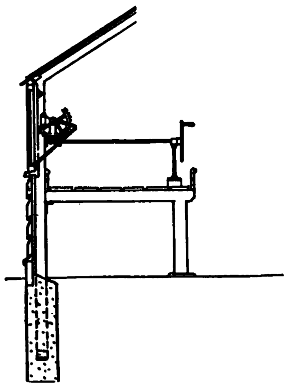

Fig. 77.—Device for operating side ventilators

Ventilator Arms.—Ventilator sash are most commonly raised and lowered by means of hinged braces or arms operated from the shafting. There are three general types.

The elbow arm is most commonly used but has the disadvantage that a long leverage is required, in order to open the ventilators to the full width, which puts a considerable strain on the shaft.

The double acting arm overcomes this difficulty to some extent as it is possible to secure a wider opening with a shorter leverage, but it is necessary to rotate the shaft through an extra half turn. On long runs these arms are now being extensively used in place of the common elbow arm.

The extending arm is used in low houses, or for side ventilators, or in other places where an elbow or double acting arm would extend into the house so far as to be in the

way. It folds together when the sash is closed and occupies little space, but it extends automatically when the shaft is turned. It is especially convenient under certain conditions, but it lacks the strength necessary for long runs.

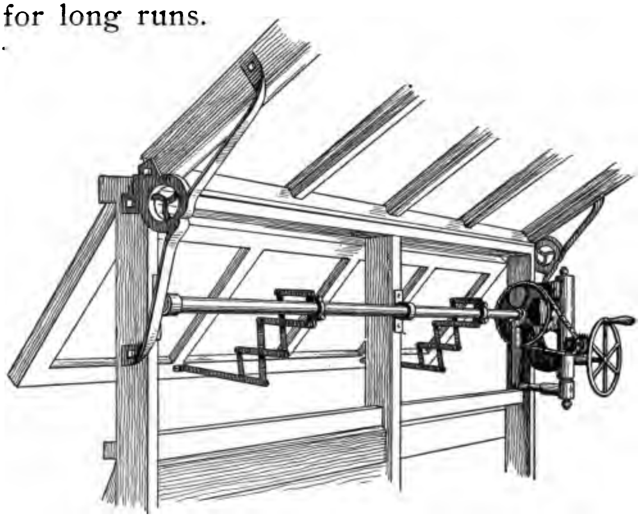

Fig. 78.—Compact machine for operating side ventilators

In all systems the arms are clamped securely and rigidly to the shafting, and as near as possible to the hangers so as not to spring the shafting when heavily loaded. They are spaced about 3 feet apart along the sash. If continuous sash are not used the arms should be distributed as follows: For sash up to 4 feet long, one arm; from 4 to 7

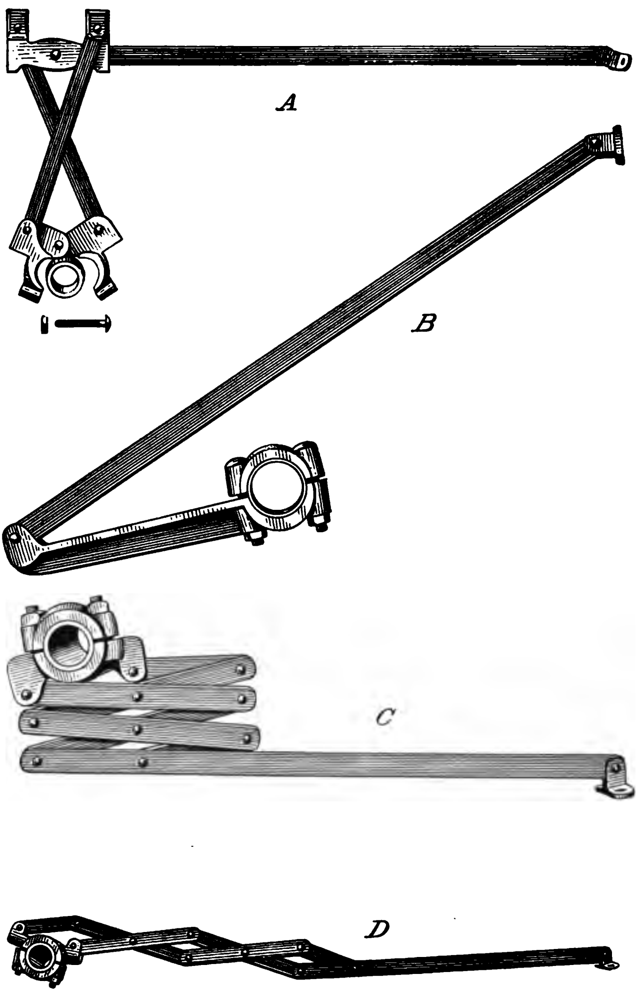

Fig. 79.—Types of ventilator arms. A, double acting arm; B, elbow arm; C, extending arm closed; D, extending arm open

feet long, two arms; and from 8 to 11 feet long, three arms, etc.

Capacity of Ventilating Apparatus.—The capacity of ventilating apparatus depends largely upon the size and method of manufacture, but the length of run is limited to the torsional strength of the shafting. In long lengths there is always more or less torsion, so that the ventilators at the extreme end do not open as wide as those close to where the power is applied. This is of little consequence in summer when the ventilators are wide open, but in winter, when only slight ventilation is required, it may result in the sash at the end of the shaft not opening at all and the ventilation will thus be uneven and unsatisfactory. Moreover, the sash are likely to be frozen down in winter and the tendency for the shafting to twist is thus increased. It is wise to have a wide margin for safety.

An indication of the length of shafting that may be used with safety is given on page 130. Tests show that one and a fourth-inch standard pipe has a torsional strength 42 per cent. greater than 1-inch

double-strength pipe and that the weights are practically the same. The price of 1-inch double-strength pipe averages about 25 per cent more than standard one and a fourth inch pipe. It is evident, therefore, that for long runs it is not only safer but more economical to use one and a fourth-inch standard pipe than 1-inch double-strength.

Generally speaking, a 150-foot run is about the limit when elbow arms are used. This may be slightly increased by using the double acting arms, and still further by using the rack and pinion system. This is equivalent to saying that the ventilators in a house 300 or 350 feet long may be operated from one station by having machines located in the center of the house and operating each way. It is economy to have all ventilator sash for one house operated from the same station if possible.

Sliding Shaft System.—In order to enable the operator to care for an extremely long line of sash from one station a sliding shaft system has been devised. In this case the shafting is solid and square, and instead of rotating it slides backward and forward, the motion being given by a pinion working on a screw or worm gear at one end of the shaft.

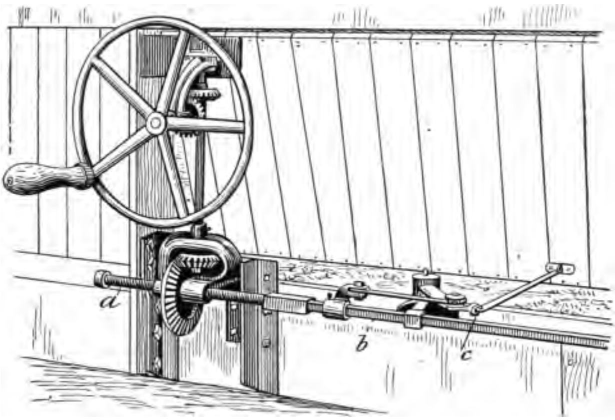

Fig. 80.—Sliding shaft system for operating ventilators

This sliding movement is utilized to operate the sash by means of a right angle lever, pivoted at the angle with the short arm attached to the shaft and the long arm to the sash. It is claimed for this system that it will operate a line of sash 500 feet long.

CHAPTER IX

BEDS, BENCHES AND WALKS

In the earlier greenhouses, plants were almost always grown on raised benches. This was partly for the convenience of the grower and partly because the houses were almost always erected with high, solid side walls and it was necessary, in order to secure satisfactory growth, to bring the plants close to the glass roof. In modern houses, when all or part of the side walls are of glass, raised benches are not so necessary, and are very commonly dispensed with and the plants grown directly in the soil which forms the floor. This is particularly true when vegetables such as lettuce, tomatoes or cucumbers are grown.

Florists, as a rule, have been loth to give up the use of benches and present the following arguments in their favor. (1) It is more convenient to care for plants when grown on raised benches than when grown on the ground. (2) Benches make possible

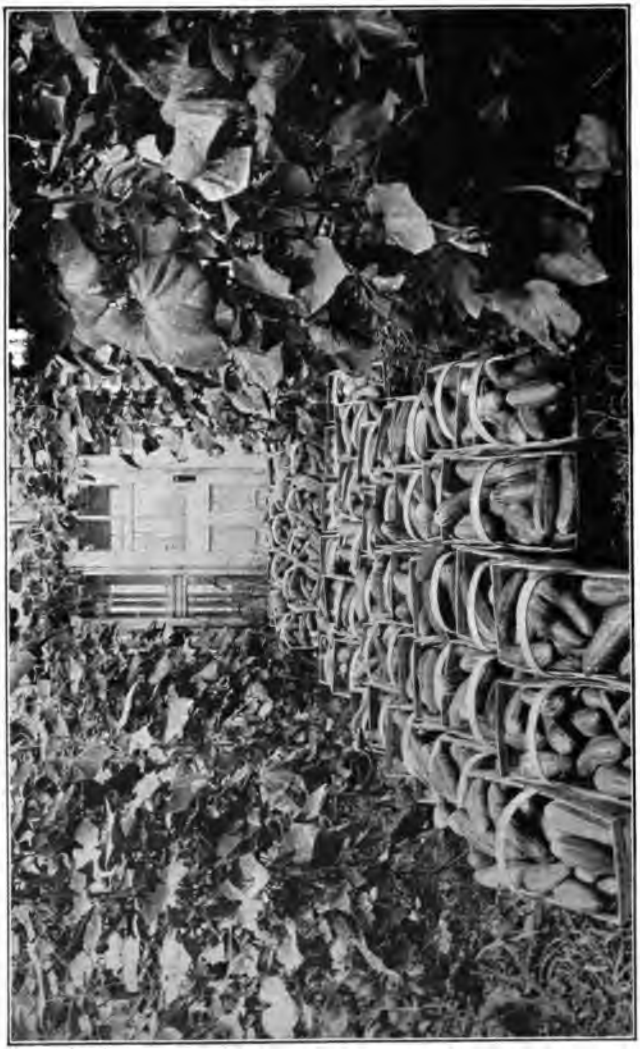

Fig. 81.—Cucumbers growing in the ground. No benches are used

the placing of the heating pipes underneath, which makes them less conspicuous and at the same time affords a method of giving "bottom heat," which is considered advantageous with many plants. (3) It is maintained that there is a better circulation of air about plants grown on benches and that the plants are less subject to disease. (4) The temperature and moisture of the soil can be more easily regulated in benches. (5) Low-growing plants make a better display when grown on benches.

The following are the most common disadvantages claimed by those who urge against the use of benches. (1) They are expensive to build and maintain. (2) They do not admit of an economical use of space. (3) The soil dries out rapidly. (4) The soil has to be changed more often. (5) It is more difficult to use labor-saving tools such as wheel-barrows. (6) All work must be done by hand. In large houses it is possible, when plants are grown on the ground, to prepare the soil with a horse or with wheel hoes. (7) With high-growing plants such as tomatoes and cucumbers, it is difficult to harvest the crop when they are grown on high benches.

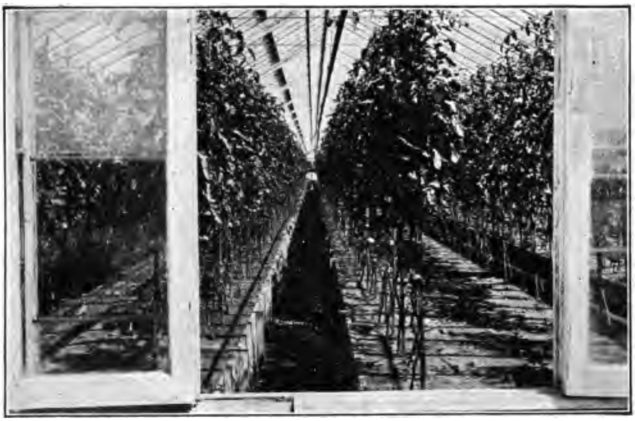

Fig. 82.—Tomatoes growing in solid raised beds

Fig. 83.—Solid raised beds of hollow building tile in use at the Michigan Agricultural College

Raised Beds.—To overcome some of the objections to raised benches, many growers use solid raised beds, the height varying from a few inches to that common for benches. Such beds dry out less quickly than do benches, the soil does not have to be removed as frequently, and they are less expensive to maintain. They are open to some of the objections urged against benches and do not possess many of the advantages afforded by culture in the open soil. The width and arrangement follows closely that of benches.

Raised Benches.—Benches are exposed continuously to conditions which favor their rapid deterioration. Unless well constructed of good material, they are a source of constant annoyance. Many growers use wooden benches. Others use benches having iron frames, and sides and bottoms of wood, tile, slate or cement slabs. Still others use solid concrete benches. All forms have their advantages and their advocates.

Wood Benches.—Wood benches have the advantage of slightly less first cost, though if good material is used, the cost will be nearly as great as for iron frame benches. In permanent houses nothing but cypress or

cedar should be used, genuine pecky cypress being undoubtedly the best. The sides and bottom boards are not less than 1 inch thick. The side boards are 8 inches wide.

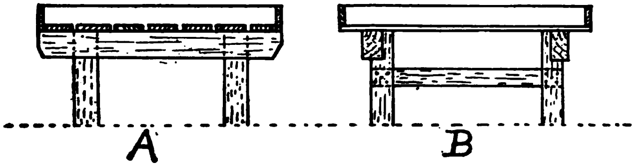

Fig. 84.—Two types of wood benches. A, bottom boards running lengthwise; B, bottom boards running crosswise

The width of the bottom boards is immaterial, except that when in place they have a space of a fourth-inch between them for drainage. They are usually run lengthwise of the bed and are supported by cross-beams, spaced not more than 4 feet apart.

The size of the cross beams will depend somewhat on the width of the bench, as follows:

For benches up to 4 feet wide........2x4 inches
For benches from 4 to 6 feet wide....2x6 inches
For benches over 6 feet wide.........2x8 inches

The legs or posts are at least 4 x 4 inches in size, and rest on concrete or brick piers. Sometimes, when cement walks are used, they are made to extend under the benches far enough to act as a foundation for the posts.

To guard against warping of the side and end boards of wood benches, angle irons may be used in the corners and along the sides, and fastened by screws or small bolts. Brick piers may be used in place of the wooden legs. The wooden legs, however, will usually outlast the bottom boards and cross-beams.

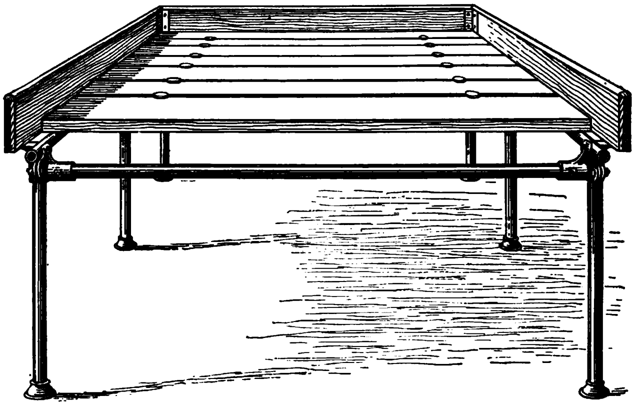

Fig. 85.—A type of iron frame bench

Iron Frame Benches.—In the majority of iron frame benches, 1-inch wrought-iron pipe is used. It is rarely threaded but is tied together with split malleable iron castings by the use of bolts and set screws. The sides and bottom may be made of wood, iron, slate, tile or even of cement slabs. All are

removable and may be replaced without taking down the frame.

Iron frame benches with cypress sides and bottoms are now much in favor. They are but little more expensive than the all-wood benches and are in most cases more satisfactory, as the frames are nearly indestructible. They should, however, be made of wrought-iron pipe rather than of steel. They may be had in two forms, one in which the bottom boards run lengthwise of the bench and another in which they run crosswise. The advantage of the latter is that short lengths may be used. These benches may be purchased with all parts cut to order, or they may be easily cut by anyone familiar with pipe cutting.

Iron frame benches are also made of angle iron or structural iron of different forms. The chief disadvantage of these is that the iron cannot be worked readily by the ordinary workman and must be cut and fitted at the factory.

Concrete Benches.—Concrete, because of its permanency, is often recommended for greenhouse benches, and its use is increasing. In general, there are two separate

Fig. 86.—Greenhouse bench of concrete. The bottom is made of slabs of concrete

types. In one type the legs, bottom and sides are cast separately in molds and then put together in the greenhouse. In the other type the whole bench is cast in a form built in the house where it is to stand. There are at least two firms having patents on cement greenhouse benches and who are prepared to sell or rent molds or forms for making them. It is also possible for a skilled mechanic to make forms to suit any special location or for any form of bench. In making concrete benches, care should be taken to provide for adequate drainage through the bottom and to see that they are thoroughly reinforced.

There has been some discussion as to the effect of concrete benches on the growth of plants. The author has had but little practical experience with them but quotes from one of the largest users of concrete benches in the country, as follows:

"At my place I use only concrete benches and the results and advantages have been very satisfactory, but I want to be open and frank concerning the disadvantage, which is only for the first year. Something in the line of a chemical of a whitish nature appears on fresh new cement, and that seems

to be injurious to plants; but after you have filled the benches with soil and used them the first year, the soil generally eats or absorbs this chemical, and the roots of carnation plants or anything else cling to the cement slabs the same as they do to slate. A good remedy to get rid of this so that it will not injure the plants is simply to put air-slaked lime or rather heavy whitewash on the inside of the bench, and that seems to protect the plants from coming in contact with the chemical mentioned."

Height and Width of Benches.—The height of greenhouse benches is largely determined by that most convenient for the operator to work. This in turn depends upon the nature of the plants to be grown. For example, when low-growing plants like lettuce are grown, a bench 32 inches high is about right; but when carnations are grown this may be so high as to make disbudding difficult. This refers to the distance from the top of the walk to the top of the sides of the bench.

The width of the bench depends on the width of the house, on the arrangement of the benches, and to some extent on the kind

of plants to be grown. It is limited to the distance a man can conveniently reach in caring for the plants. This distance is about 2½ feet or rarely 3 feet. In other words, benches that can be worked from one side only should be no more than 2½ or 3 feet wide, and benches which may be worked from both sides should be no more

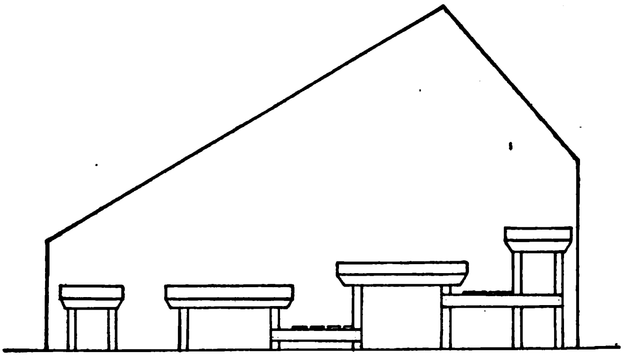

Fig. 87.—Method of arranging benches in an uneven-span house to secure best advantage of the sunlight

than 5½ or rarely 6 feet wide. In uneven span houses it is sometimes advisable to elevate the walks and benches.

Arrangement of Benches.—This is governed by the width of the house, the use for which the house is designed, the height of the beds or benches and by the individual preference of the owner. Commercial grow-

ers look upon walks as waste space and endeavor to keep them as narrow as is consistent with ease and economy in getting about the houses. In private houses, conservatories and show houses, the walks are sufficiently wide to allow two persons to pass easily.

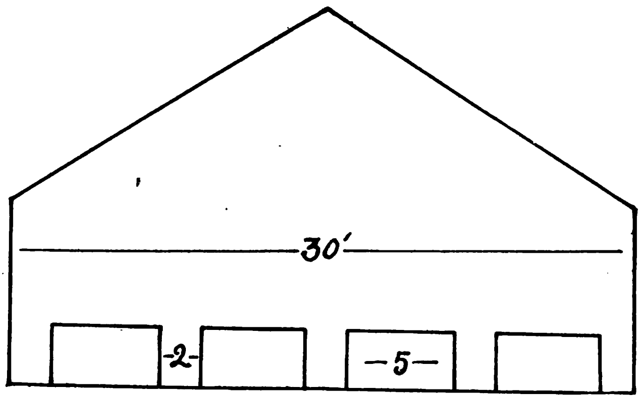

Fig. 88.—An arrangement of benches in a 30-foot house. Only 66 2-3 per cent of the floor space available for crops

In figures 88 and 89 are illustrated two methods of arranging benches in a 30-foot house. By the first method four benches, each five feet wide, are provided and 66⅔ per cent of the floor space is available. By the second method three wide and two narrow benches are provided and 73⅓ per cent of the floor space is available. In the latter method

the side benches extend the entire length of the house and one walk is eliminated.

It is worth while to exercise considerable care in determining the arrangement of the benches, especially in commercial houses. As a rule a walk along the side of a house is an extravagance. When the width of the

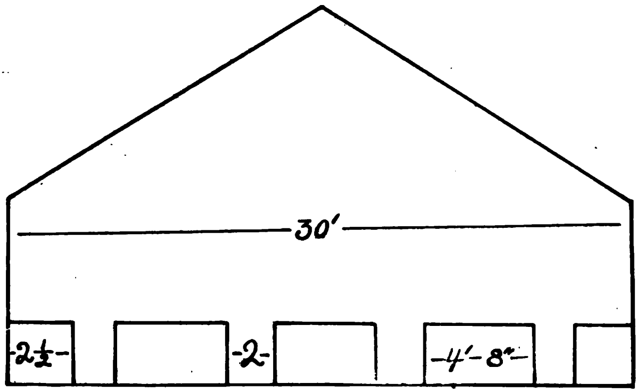

Fig. 89.—Another arrangement of benches in a 30-foot house. By this arrangement 73 1-3 per cent of the floor space is available for growing crops

house admits, it is usually more economical to have narrow benches along each side.

When low beds are used, the walks may be narrower than with high benches as people can pass more readily. In conservatories and show houses 3 feet is none too

wide. In commercial houses with high benches, from 20 to 24 inches is a common width. When low beds are used, the walks are sometimes as narrow as 14 or 16 inches.

It is often advisable to arrange the benches so as to have the center walk of extra width, which will allow of the use of a wheel barrow or cart in removing and replenishing the soil and for other purposes.

Material for Walks.—Concrete is unquestionably the best material for walks. Water has no effect on it; it is substantial; it may be used as a foundation on which bench legs and ventilator columns may stand; and it may be quickly and easily laid. In conservatories and private houses nothing can take its place. For data on concrete construction see Chapter XIV.

In commercial houses coal ashes are often used. Ashes must be kept away from the pipes as the sulphur they contain will cause the pipes to corrode very rapidly.

Curbs.—For convenience and cleanliness, many growers who plant directly on the ground prefer to have their houses marked off into regular beds, divided by narrow walks and surrounded by a curb to keep the

soil in place. In time, the constant addition of manure raises the soil in these beds so that they become in reality raised beds. Board or plank curbs are rarely satisfactory, as the moisture of the soil on one side causes them to warp. The most satisfactory and economical curbs are made of concrete, which is heavily reinforced with iron rods when it is poured.

CHAPTER X

GREENHOUSE HEATING

Generally speaking, there are only two satisfactory methods of greenhouse heating: Steam and hot water. Direct heating by stoves is not satisfactory even in small houses, and no satisfactory system has yet been devised for the use of hot-air furnaces. The only method aside from steam or hot water which deserves mention is heating by flues. They are wasteful of fuel, and their use is not justified, except in cheaply constructed houses which are used only for a few months in the spring or fall.

The principles pertaining to greenhouse heating are much the same as those involved in heating other buildings, except that the loss of heat is greater from glass than from wood or brick walls, and a higher and more constant night temperature is required than is necessary in dwellings. For this reason, relatively more radiating surface is required and boilers of larger capacity are needed.

Heating with Flues.—In heating with flues the equipment consists simply of a furnace at one end of the house and a chimney at the other, the two being connected by a flue, carried underneath the bench or buried just underneath the soil, through which the heat and smoke are carried. This may be made of brick, but large-size drain or sewer tile are more commonly used. These withstand the heat and are easily and cheaply put in place. It is best to have the flue slope upward slightly toward the chimney. As has already been stated, this method is wasteful of fuel. It is also difficult to regulate. It is still employed to some extent by vegetable gardeners in cheap houses, used only in late winter or early spring for the starting of early vegetable plants, sweet potatoes, etc.

Hot Water vs. Steam.—There has been much discussion as to the relative virtues of hot water and steam for use in greenhouse heating. It may be well to consider here some of the advantages claimed for each. For hot water the following are claimed: (1) It provides a more even heat than steam. (2) The radiating pipes are not so hot, and

plants near them are less likely to be injured than when steam is used. (3) It requires less frequent firing, since warm water is always circulating in the pipes as long as there is any fire in the furnace, whereas, with steam it is necessary to keep the water boiling to keep steam in the pipes. (4) For the above reason a night fireman is not required in small houses equipped with hot water. (5) It is less dangerous. This is more apparent than real, for steam is usually carried at low pressure. (6) It is claimed that hot water requires less fuel. Theoretically this should be true, but in practice it has not been very definitely proven. (7) Water will hold heat for some time if the fire should accidentally go out.

The following advantages are claimed for steam: (1) Less cost of installation. (2) Steam requires fewer radiating pipes hence less shade is cast when the pipes are placed overhead than when hot water is used. (3) Less time is required to get up heat, as there is a relatively small body of water. (4) A greater area may be warmed from a given heating plant than with hot water, for the steam may be forced farther. (5) A steam

plant may be used to furnish steam for soil sterilization.

All the above apply more especially to small ranges than to large ranges. As a rule, hot water is more generally used in ranges covering up to 20,000 square feet and steam in larger ranges, although there are many exceptions. At present the tendency seems to be toward the use of hot water rather than steam.

In an investigation recently made by the author among a large number of greenhouse owners, 86 per cent. of those having 20,000 square feet or more under glass preferred steam heat. The chief reasons stated were, "better control," "cheaper maintenance," and "less shade from pipes." Six per cent. preferred a combination of hot water and steam. The remaining 8 per cent. preferred hot water, stating as their reasons, "steadier heat," "plants grow better," "pipes do not rust out during the summer as with steam," and "cheaper to operate in spring and fall when little heat is required."

Of those having less than 20,000 square feet under glass, 74 per cent. preferred hot water, giving in addition to the reasons

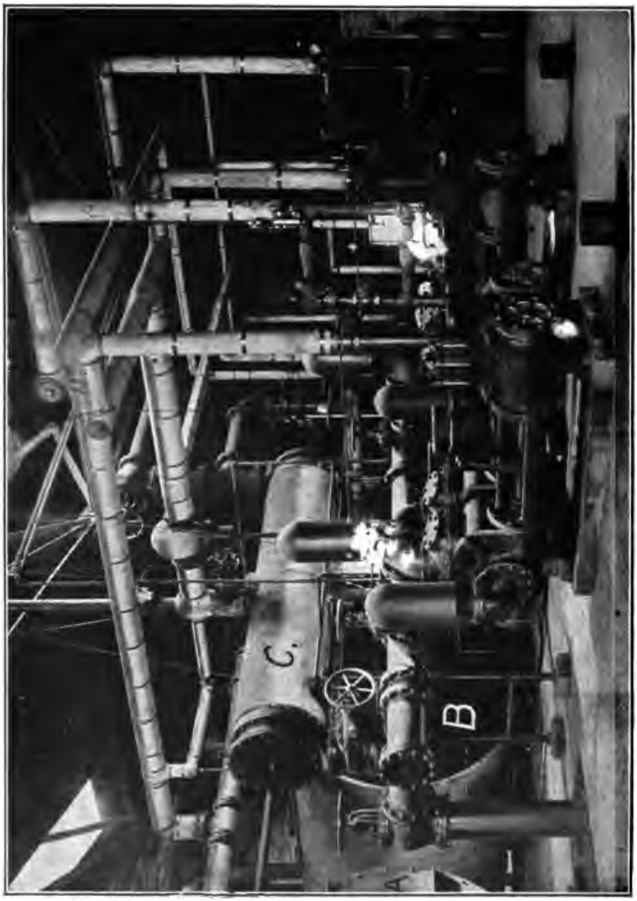

Fig. 90.—A combination steam and hot-water heating system. A, hot water boiler; B, steam boiler. Steam from B is used to pump the hot water about the range and the exhaust and superfluous steam is used to heat water in the tank C which is connected with the regular heating system

named above, "less labor to fire, especially at night" and "needs no night fireman."

Combination Systems.—A combination of hot water and steam may often be used to advantage. By this means steam may be had for power and at the same time be utilized for heating. In cold weather both boilers may be used for heating, while in mild weather the steam boiler alone may be used, thus furnishing the necessary heat and power.

Another and more simple combination of hot water and steam heating which, however, is more expensive in installation, consists of two separate sets of heating coils, one of which is connected with a steam boiler and the other with a hot water boiler. The steam is used when a small amount of heat is needed quickly on cold nights in early fall or late spring, and to supplement the hot water in severe winter weather.

In any system of heating it is much safer, as well as more economical in operation, to install two or more boilers rather than to depend on one large one. Both may be used in severe weather and in case of accident to one, the other may be forced for a

few days and thus protect the plants from injury by freezing, which would inevitably result if only one boiler was in use.

Heating Coils.—Because of the large amount of heating surface required, and because all parts of a greenhouse must be kept at as nearly uniform temperature as possible, radiators such as are used in private houses have not been found practicable in greenhouse heating. Instead, long coils of wrought iron or steel pipe are used. For steam heating these coils are commonly of 1 or 1¼-inch pipe. In hot water heating they are slightly larger, varying from 1¼ to 2 inches. In the early days of hot water heating large cast-iron pipe, often as large as four or five inches in diameter was used. It is still used to some extent, but more often in small private conservatories than in commercial houses.

There is very little to be said in favor of using cast-iron pipes. The fact that they are now so little used shows that they have no special merit. The smaller, wrought pipe is lighter and much more easily handled; is screwed together instead of caulked with lead and oakum; has much more radiating

surface in proportion to the volume of water contained; can be placed along the side walls or hung on the supporting posts in-

Fig. 91.—Under-bench heating with large cast-iron pipes

stead of having to be supported on masonry piers; and permits of a more perfect control of the heat.

Heating coils are made by joining several pipes together by means of headers. The hot water is conducted to the coils from the boiler by means of a larger pipe known as a flow pipe or feed pipe. It is returned to the boiler by means of a return pipe. In steam heating the coils are often so arranged that the water formed from the condensed steam returns to the boiler through the flow or feed pipe, instead of through a separate return pipe.

CHAPTER XI

HOT WATER INSTALLATION

General Principles.—Before discussing the installation of a hot water heating system it is necessary to have in mind the physical and mechanical principles involved. Briefly they are these: Water increases in volume as it is heated and it is consequently lighter in weight. When a fire is lighted under a water boiler the water around the heating surface expands and, being lighter, is forced upward by the heavier, colder water. Popularly speaking, the hot water "rises."

The practical problem is to conduct the hot water from the boiler to the coils where the large radiating surface permits the water to give up its heat to the air in the house and then, as it becomes colder and heavier, to conduct it back to the boiler where it will displace the warmer and lighter water there. Gravity is the force utilized to produce circulation. It acts with a force proportional to the difference in weight between the column of warm water and the column of cool water.

The following table shows the weight of a cubic foot of distilled water at different temperatures.

32	degrees F.	.62.42	pounds	170	degrees F.	.60.77	pounds
100	"	....62.02	"	180	"	..60.55	"
110	"	....61.89	"	190	"	..60.32	"
120	"	....61.74	"	200	"	..60.07	"
130	"	....61.56	"	210	"	..59.82	"
140	"	....61.37	"	220	"	..59.76	"
150	"	....61.18	"	230	"	..59.37	"
160	"	....60.98	"				

From the above table it is apparent that a cubic foot of water entering the boiler at 140 degrees is 0.82 pounds heavier than an equal quantity leaving the boiler at 180 degrees. It is evident that the higher the columns of water the greater will be the difference in weight, and consequently the more rapid will be the flow.

The various factors influencing the velocity of water in a gravity hot water system are embodied in the following formula.

$$V = \sqrt{\frac{2gh\ (w-W)}{(w+W)}}$$

In this formula, V=the velocity in feet per second, g=the force of gravity (32.16), h= the total height of the system, W=the weight of a cubic foot of water when it leaves the

boiler and w=the weight of a cubic foot of water when it enters the boiler.

This, of course, disregards friction. The practical application is that when it is desired to increase the velocity of the water; e.g. in long runs, it may be done by either lowering the boiler or by raising the height of the flow pipes.

The following table shows the velocity in feet per second in a hot water system under various conditions.

Height of Column	Difference in temperature on leaving and entering boiler					
	5°	10°	15°	20°	30°	40°
	Feet per second					
5 ft.	0.541	0.750	0.922	1.09	1.33	1.51
10 "	0.765	1.06	1.32	1.55	1.88	2.04
20 "	1.085	1.50	1.85	2.19	2.66	3.01
30 "	1.35	1.83	2.26	2.68	3.26	3.71

Arrangement of Piping.—There are two approved methods of arranging the piping for hot-water heating. One is known as the "down hill"; the other as the "up hill." In the former the highest point in the system is directly above the boiler. In the latter the highest point is at the end of the system farthest from the boiler. Either is satisfactory and is preferred to the "level" system sometimes advocated. In either the "down

hill" or the "up hill" system the air which collects in the pipes will eventually reach the highest point when it may be allowed to escape through an automatic air valve. In the "level" system slight sags and raises are likely to occur and the air will collect in the higher parts and cause trouble.

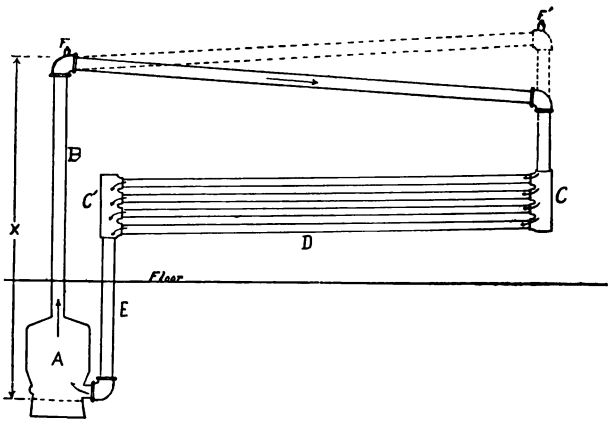

Fig. 92.—Diagram showing "down-hill" and "up-hill" systems of piping. A, boiler; B, flow pipe; C, C', headers; D, radiating pipes or coils; E, return pipe; F, automatic air valve; x indicates height of water column

The author prefers the "down hill" system when the flow pipes are carried in the upper part of the house and the coils are considerably lower. When all the pipes must be in the lower part of the house, or under the benches, he prefers the "up hill" system. The

majority of greenhouse operators seem to be in accord with this view. Practically speaking there appears to be but little difference in the efficiency of the two systems and the convenience and the arrangement of the house determines the choice to a considerable extent.

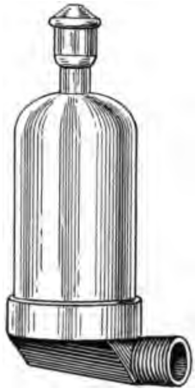

Fig. 93.—A type of automatic air valve

Estimating Radiation. — The calculations for greenhouse heating are based on certain fundamental facts which for hot water may be stated briefly as follows: A square foot of glass will give off, under ordinary greenhouse conditions in winter weather, approximately 1 B. T. U.* of heat per hour, for each degree difference in temperature between the air inside the greenhouse and that outside. A good wood, brick or concrete wall will give off about a sixth as much, or a sixth B. T. U. per square foot per hour. It is customary to divide the total wall surface by six and consider it as equivalent to glass.

*British Thermal Unit; the amount of heat required to raise one pound of distilled water from 62 to 63 degrees F.

To arrive at an estimate of the possible heat loss from a greenhouse add to the total square feet of exposed glass surface a sixth of the total square feet of exposed wall surface, and multiply the sum by the difference between the temperature at which the house is to be kept and the lowest outside temperature which will probably be experienced. Suppose, for example, that a house has 10,000 square feet of glass and equivalent glass, that it is desired to keep it at a night temperature of 50 degrees, and that the lowest outside night temperature to be expected is —10 degrees. The number of B. T. U. given off by such a house under these conditions would be [50°— (—10°)] x 1 x 10 x 10,000 or 600,000 B. T. U., and enough heating coils must be provided to supply this amount.

In hot water heating the coils will give off approximately two B. T. U. per square foot of surface per hour for every degree difference in temperature between that of the coil and that of the surrounding air. The average temperature of the coils may be taken to be 160 degrees, and if the house is to be maintained at 50 degrees the difference will be 110 degrees. Multiplying 110 by 2

we have 220 or the number of B. T. U. given off by each square foot of radiating surface per hour. If, then, we divide 600,000 by 220 we have 2,727 which is the number of square feet of radiating surface to be provided.

These principles may be embodied in the following formula where R= the amount of radiating surface required in square feet; T, the temperature to be maintained inside the house; t, the lowest outside temperature to be expected; and G, the number of square feet of glass and equivalent glass.

$$R=\frac{(T-t) \times G}{(160-T)\ 2}$$

This formula gives a wide margin of safety. Most builders prefer to use considerably less radiating surface and depend on forcing the furnace in extremely cold weather. By so doing the temperature of the coils may be kept at 180 degrees or even considerably higher under favorable conditions and the amount of radiation required will be correspondingly less.

Amount of Pipe Required.—Having estimated the amount of radiation required the next problem is to find the quantity of pipe

necessary to provide this amount. For example, 1 linear foot of 1½-inch pipe furnishes about half a square foot of radiating surface. Divide the number of square feet of radiation required by the outside area of a linear foot of pipe of the desired size. The result will be the number of linear feet of pipe required. From this is subtracted the amount of radiation supplied by the flow or feed pipe and other fittings.

The following table gives the radiating area in square feet of a linear foot of pipe of various sizes.

Size of pipe	Radiating surface of 1 linear foot
¾ inch	0.27 square feet
1 "	0.35 " "
1¼ "	0.43 " "
1½ "	0.49 " "
2 "	0.62 " "
2½ "	0.75 " "
3 "	0.91 " "
3½ "	1.05 " "
4 "	1.18 " "

For practical purposes the following general rule will give approximately the amount of radiating surface required. Divide the number of square feet of glass and

equivalent glass:

By 6 to heat the house to 40 degrees
By 4 to heat the house to 50 degrees
By 3.5 to heat the house to 60 degrees
By 3 to heat the house to 70 degrees

The quotient will be the square feet of radiating surface required.

Size of Flow Pipe.—Having determined the amount of radiation necessary, the next problem is to determine the size of the flow or feed pipe required to supply the coils. Experience has shown that it is not necessary for the supply pipe to be equal in capacity to the sum of the capacities of the coil pipes. The correct size may be determined, theoretically, by the use of the following rather tedious formula:

$$A = \frac{H\ R}{25wvt}$$

In this formula A=the cross section area in square inches of the flow pipe; H, the total radiation in B. T. U. per hour given off by the coils; R, the radiating surface in square feet; w, the weight of the water per cubic foot; v, the velocity of feet per second; t, the difference in temperature between the water when it leaves the boiler and when it returns.

This formula is seldom used but the fol-

lowing table has been derived from it. To use, measure the height of the water column in feet, find from the table the factor for this height, and multiply the square root of the radiating surface in square feet by this factor. The result will be the size of the flow pipe, in inches (diameter) required. This is based on the assumption that there is a difference of 10 degrees in temperature between the water when it leaves and when it enters the boiler.

Height of Column (ft.)	Diameter Factor
5	0.133
10	0.113
15	0.104
20	0.095
25	0.091
30	0.187

For example, to supply a coil of ten 1½-inch pipes 100 feet long (500 square feet) 15 feet above the bottom of the boiler, would require a feed pipe the diameter of which would be represented by $\sqrt{500} \times 0.104$ equals 22.4×0.104 equals 2.33 or a 2½-inch pipe.

Short Methods.—The above formula takes into consideration the fact that the greater the height of the column of water the more rapid the flow and consequently

the smaller may be the supply pipe used. In greenhouse heating, however, the height is seldom very great, usually varying between 8 and 20 feet, so that the following rule of thumb usually proves satisfactory. The flow pipe should be one pipe size greater in diameter (inches) than the square root of the radiating surface of the coil (in square feet), divided by 10. Applying this rule to the above problem we have $\sqrt{500} \div 10 = 2.24$ The next pipe size is 2¼ inches but this is so close to the estimated size that a 2½-inch pipe should be used to insure efficiency.

The size of the main supply pipe from the heater is determined in the same manner by taking the sum of all the radiating surface to be supplied. It is better to have one main flow pipe leading from the boiler, from which branches to the various coils may be taken, than to have a flow pipe direct from the boiler for each coil, though two or more flow pipes may be taken off. The return pipes should be of the same size as the flow pipes. The flow pipe is taken from the top of the boiler and the return pipe enters at the bottom.

In Fig. 94 is shown a diagram of a method for piping a medium-sized house. In the dia-

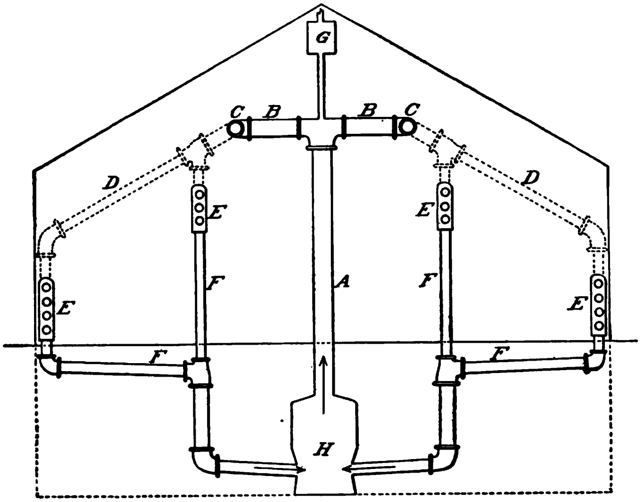

Fig. 94.—A method of piping a medium size house

gram A is the flow pipe extending directly up from the boiler; B, B, branch flow pipes; C, C, branch flow pipes extending the length of the house; D, D, distributing pipes at the opposite end of the house; E, E, E, E, the return coils; F, F, F, F, return pipes; and G, expansion tank.

Valves should be conveniently placed so that any or all of the coils may be cut off individually. They may be placed either in the flow or return pipe, or in both. If there is a valve in both the supply and return from each coil, any one may be repaired in case of an accident without drawing the fire or inter-

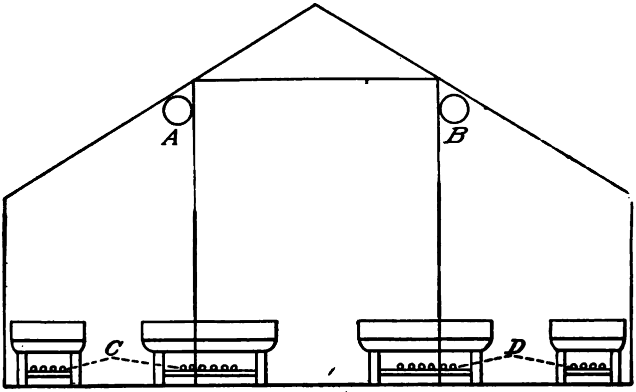

Fig. 95.—Diagram showing under-bench method of hot water piping. A and B flow pipes; C and D heating coils

fering with the circulation in the other coils. The valves should be of a type which, when open, cause as little resistance to the flow of water as possible.

Length of Coils.—The length of the coils which may be used depends: (1) Upon the height of the column of water; (2) upon the size of the pipes which make up the coils; and (3) the amount of friction in the coils and fittings. The length of coils which may be satisfactorily used with pipes of various sizes are given in the following table.

Size of pipe	Length of coil
1 inch	Up to 50 feet
1¼ inch	50 to 75 feet
1½ inch	75 to 100 feet
2 inch	100 to 150 feet

This table is based on the supposition that gravity, only, is to be depended upon for circulation. When pumps are used to cir-

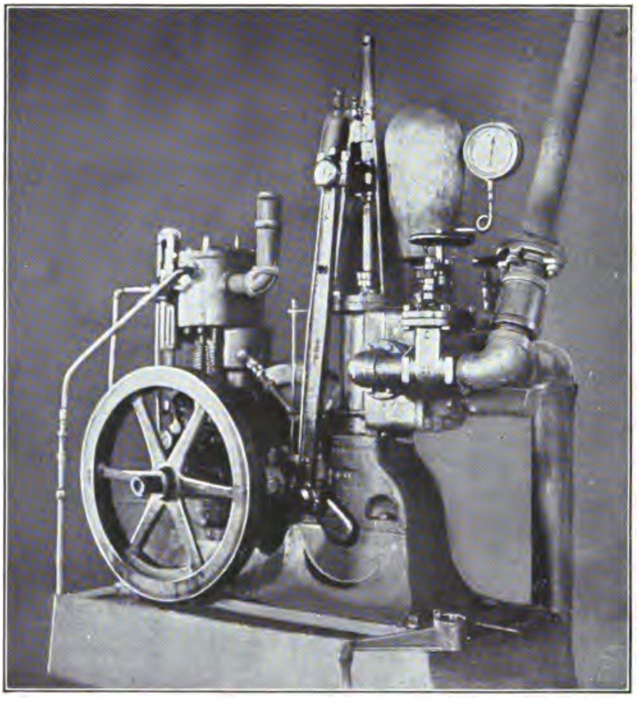

Fig. 96.—Gasoline engine arranged to circulate hot water in a greenhouse heating system

culate the water the length may be materially increased.

The most commonly used size is 1½-inch, and when the houses are much over 100 feet in length two or more coils may be used, each extending only a part of the length, and having separate feed and return pipes.

Expansion Tank.—Water expands in heating. It is necessary, therefore, to make some provision to take care of the expansion, in order that the pipes shall not burst and to keep them full at all temperatures. This is accomplished by connecting the system with an expansion tank into which the excess water will flow as it expands, and from which it will flow back into the system as it cools. It is placed at or above the highest point in the system, but it may be connected with any part of the system or even with the boiler.

The size of tank required is directly proportional to the volume of water contained in the system and is determined by the amount of expansion resulting from heating. The following table adapted from Kent shows the relative amount of expansion.

Temperature Cent.	Temperature Fahr.	Comparative Volume
4°	39.1°	1.00000
10°	50. °	1.00025
20°	68. °	1.00171
30°	86. °	1.00425
40°	104. °	1.00767
50°	122. °	1.01186
60°	140. °	1.01678
70°	158. °	1.02241
80°	176. °	1.02872
90°	194. °	1.03570
100°	212. °	1.04332

From the above table it will be seen that the increase in volume from 50 to 212 de-

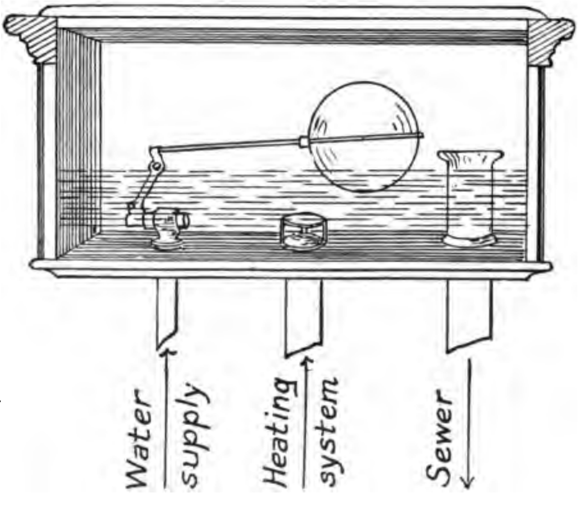

Fig. 97.—Automatic expansion tank. This is connected with the city water system and will automatically keep the heating system filled. See also G, Fig. 94

grees is 1.04432—1.00025=0.04307, or a little more than 4 per cent. It is customary to make the expansion tank large enough to hold 5 per cent. or a twentieth of the water contained in the system, including the boiler. Thus, if the system contains 100 gallons, the supply tank should be large enough to hold a twentieth of that amount or 5 gallons.

The capacity in gallons of a linear foot of standard wrought pipe is shown in the following table.

Size of pipe diam. in inches	Capacity per linear foot	
1	0.1408	gallons
1¼	0.0638	"
1½	0.0918	"
2	0.1632	"
2½	0.2550	"
3	0.3672	"
4	0.6528	"
5	1.0200	"
6	1.4690	"

Pressure Systems.—Water in an open kettle cannot be heated above 212 degrees at sea level. At that temperature it boils and all further heat energy is expended in vaporizing the water. In an open hot-water heating system the same is true, except that the

slight pressure of the column of water in the system may permit the water in the boiler to reach a temperature slightly above 212 degrees. If water can be kept under pressure it may be raised to almost any desired temperature, and in a heating system this would mean less necessary radiating surface. The boiling point of water under various pressures above normal or atmospheric pressures is shown in the following table:

Pounds pressure	Boiling point
Normal	212.0° Fahr.
½ pound	213.7° "
1 "	215.3° "
2 "	218.5° "
3 "	221.5° "
4 "	224.4° "
5 "	227.1° "
6 "	229.7° "
10 "	240.0° "

Several systems have been evolved to produce pressure in a heating system. One of the earliest was the closed tank system in which the expansion tank was made air-tight and fitted with a safety valve set so as to let the air in the tank escape at a certain pressure. By this means the water in the coils may be made to reach a temperature considerably above the boiling point.

Recently various automatic devices using a column of mercury to produce the same result have been placed on the market. One model is designed to be placed in the pipe leading from the return pipe to the expansion tank, the tank in this case being open. The advantage of these devices over the closed tank system lies in the fact that they are less likely to become clogged and stick than are the safety or pop valves.

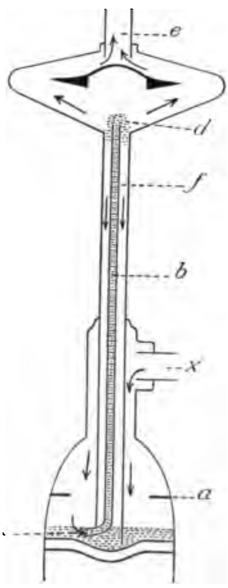

Fig. 98.—A type of mercury "generator"

In action these so-called "generators" operate as follows: The pressure is determined by the height of the column of mercury. When there is no heat in the boiler the mercury is in the position shown at **a**, Fig. 98. As soon as the water becomes warm it expands and flows in through the opening **x**. This forces the mercury down in the cistern and up through the small pipe **b**. The amount of mercury is so arranged that when it is pushed down to the level of the

curve in the outlet pipe at **c** it overflows at **d.** This allows some of the water to escape, and this goes up through the pipe **e** to the expansion tank, but the mercury being heavier falls back again through **f** to the cistern.

This automatically keeps the pressure at any predetermined point, usually about 10 pounds, which makes possible the heating of the water to a temperature of 240 degrees. This makes practical the heating of the coils to a high temperature in severe winter weather and at the same time permits the system to be run at lower temperatures in mild weather. In this respect it has the advantage over steam. It is claimed for these mercury "generator" devices that they greatly improve the circulation of the water in a heating system.

The most apparent advantage is that they make possible the use of less radiating surface, hence the first cost is less. It is but fair to say that, as a rule, growers who have installed them have found them satisfactory. When the hot water is circulated by pumps it is possible, though probably not desirable to maintain a high pressure. Economy in heating by hot water lies in having abundant radiating surface and rapid circu-

lation and then keeping the water at a moderate temperature.

Caution.—In any system see that the expansion tank and the pipe leading to it are placed where they will not freeze. As there is ordinarily no circulation in the water they contain they will freeze if placed where the temperature falls below freezing. The results will almost surely be disastrous.

CHAPTER XII

STEAM INSTALLATION*

General Principles.—In steam heating there is no circulation in the same sense that there is in hot water heating, but the steam is conducted into the heating coils, where it condenses. In condensing it gives up its "latent" heat. The water of condensation, which occupies only about 0.017 part of the space occupied by the steam, finds its way back to the boiler either by flowing back through the supply pipes, or through return pipes connected with the opposite ends of the coils. The latter system is most commonly used in greenhouse heating.

In contrasting steam and hot-water heating it is well to keep in mind the fact that only 180 B. T. U. are required to raise one

*In order to avoid repetition steam heating is discussed largely in contrast to hot water heating, as described in the preceding chapter. Both chapters should be read by one wishing to inform himself on steam heating.

pound of water from 32 to 212 degrees but that 966 B. T. U. (usually considered as 1000) are required to change a pound of water at 212 degrees into steam. When the steam is condensed in the coils it gives off this heat. This is known as the latent heat of steam. It may be defined as the amount of heat absorbed in changing from a liquid to a vapor or the amount given off in changing from a vapor to a liquid state.

The problem in steam heating is to supply an amount of radiating surface sufficient to condense enough steam to furnish the amount of heat required. Under ordinary greenhouse conditions a square foot of steam radiating surface may be counted on to condense approximately one quarter pound of steam per hour. Each square foot of radiating surface will, therefore, provide a fourth of 960 or approximately 240 B. T. U. per hour.

The number of B. T. U. required per hour to heat a given house (see page 172), divided by 240 will give, therefore, the number of square feet of steam radiation required, and from the table on page 174 the number of linear feet of pipe may be easily determined. Assuming a steam pressure of five pounds

per square inch the following rule will be found useful in determining the amount of steam radiation required for a house when the lowest outside temperature to be expected is not lower than zero.

Divide the number of square feet of glass and equivalent glass.

By 9 to heat house to 40 degrees
By 7 to heat house to 50 degrees
By 6 to heat house to 60 degrees
By 5 to heat house to 70 degrees

The quotient will be the number of square feet of radiating surface required

Size and Length of Coils.—There is less friction in steam than in hot-water heating, and for this reason smaller pipes may be used in the heating coils. They are seldom larger than 1½-inch, and 1¼-inch is very commonly used. Even 1-inch pipe may be used in comparatively short runs. Smaller pipes may also be used in steam than in hot-water heating, for the reason that the radiation per square foot of surface is greater and therefore less surface is required. In other words, an equal number of smaller pipes or a smaller number of pipes of equal size may be used in steam than in hot-water heating. Small pipes furnish a greater amount of radiation in comparison to their cubic capacity than

do large pipes. Large cast-iron pipes are almost never used in steam heating.

When 1-inch pipe is employed coils may be safely used up to 75 feet in length; 1¼-inch up to 150 feet; and 1½-inch up to 250 feet. As with hot water, better results and a more uniform temperature may be secured by using two or more comparatively short coils, rather than one which is excessively long. In small houses it is possible to run the coils entirely around the house, maintaining an even downward slope.

Arrangement of Coils.—As indicated in a preceding paragraph, either of two methods of piping may be used. In one the water resulting from the condensation of the steam

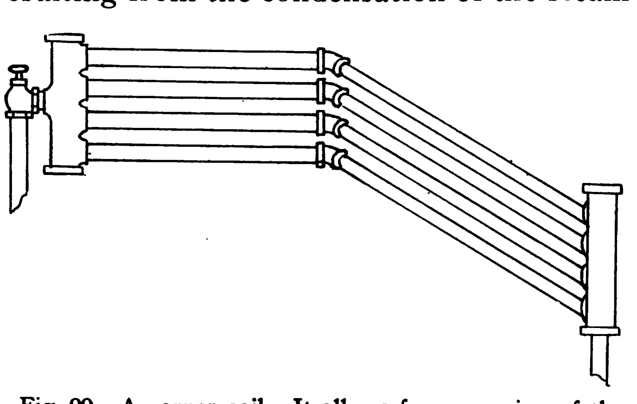

Fig. 99.—A corner coil. It allows for expansion of the pipes

flows back to the boiler through the supply pipe. In this case all pipes have an upward slope from the boiler, with no sags or pockets in which the water can collect. This method, sometimes known as the single pipe system, is very commonly used in heating dwellings where the pipes are mostly verti-

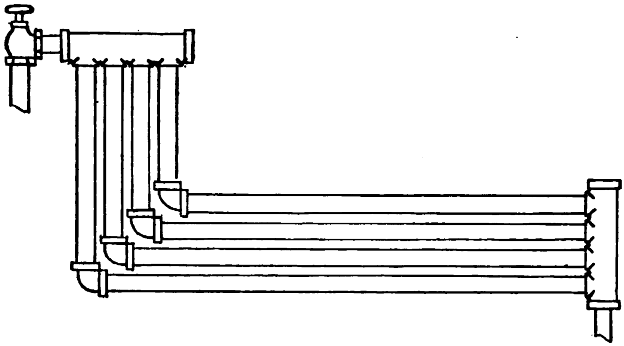

Fig. 100.—A mortise coil designed to allow for expansion of pipes

cal, but in greenhouses having long, nearly horizontal coils there is likely to be much hammering in the pipes, caused by the interference of the steam with the return water.

A more satisfactory method for greenhouse heating is to arrange the pipes much the same as in hot-water heating, proportioning the size to the supply and re-

turn pipes according to directions given in a following paragraph. This is known as the two-pipe system. The return pipe enters the boiler below the surface of the water. The coils should have a fall toward the boiler of about 1 inch to 20 feet. It is not wise to use the straight coils commonly used for hot water in steam heating as they do not allow for the unequal expansion of the pipes when the steam is turned on quickly. In steam heating special form of coils are commonly used among which are the corner coil and mortise coil.

Size of Supply and Return Pipes.—Theoretically, the size of the flow and return pipes in steam heating may be much smaller than in hot-water heating. This is especially true of the return pipe, since the water which it carries occupies only 0.017 of the space occupied by the steam from which it is condensed. In practice, however, the flow or supply pipe for steam is made nearly as large as for hot water and the return pipe only slightly smaller.

The following table shows the flow of steam in pipes of different sizes at a pressure at the boiler of approximately five pounds.

Size of pipe	Pounds of steam per hour
$1\frac{1}{2}$ inches	70
2 "	138
$2\frac{1}{2}$ "	220
3 "	390
$3\frac{1}{2}$ "	570
4 "	800
$4\frac{1}{2}$ "	1000
5 "	1400
6 "	2200
7 "	3200

To find the size of supply pipe required it is only necessary to determine the number of pounds of steam condensed per hour by the coils (approximately one-quarter pound for every square foot of radiation) and from the above table select the correct size.

The following table, adapted from Carpenter, gives the size of supply and return pipes recommended to be used in the two-pipe system for different amounts of radiation, when a pressure of not greater than five pounds is used.

Sq. ft. of radiation to be supplied	Size of supply pipe	Size return pipe
200	$1\frac{1}{2}$ inch	$1\frac{1}{4}$ inch
400	2 "	$1\frac{1}{2}$ "
700	$2\frac{1}{2}$ "	2 "
1000	3 "	2 "
1600	$3\frac{1}{2}$ "	$2\frac{1}{2}$ "
2300	4 "	$2\frac{1}{2}$ "
3200	$4\frac{1}{2}$ "	$2\frac{1}{2}$ "

4100..............5	"	3	"
6500..............6	"	3	"
9500..............7	"	..............3½	"

Valves.—In steam heating it is essential that each coil be provided with a cut-off valve. This is even more essential than with

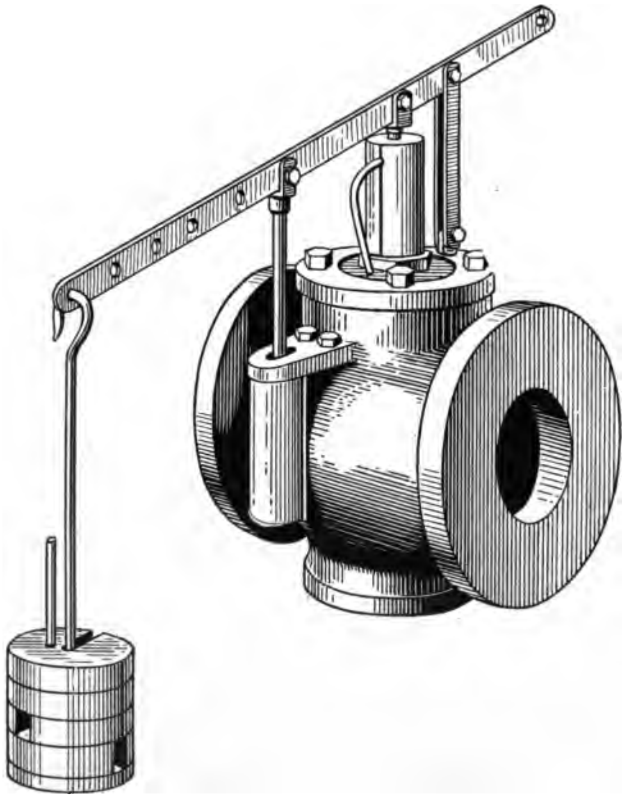

Fig. 101.—Reducing valve

hot water since with steam heating the temperature of the steam must be at least 212 degrees, while with hot water the temperature may be varied according to the weather. Automatic air valves are placed at the highest point of each coil and also in the supply pipes.

High Pressure Heating.—When steam above five pounds pressure is used it is known as high pressure heating. For greenhouse purposes high pressure heating is not satisfactory, as the pipes are too hot. In large establishments, however, a high pressure is often maintained at the boiler and is passed through a reducing valve before it enters the coils.

Vacuum and Vapor Systems.—Several heating systems are now on the market which endeavor to give to steam heating some of the advantages claimed for hot water, viz., a lower temperature of the heating pipes and less frequent attention to the boiler. They differ from straight steam heating in that a partial vacuum is maintained within the system, thus causing the water in the boiler to give off vapor at a temperature of less than 212 degrees.

There are several different systems but they may all be grouped roughly into three classes: (1) Those in which a vacuum is created by means of a pump or other mechanical device; (2) those in which the air is expelled by raising the steam to a relatively high pressure, and then preventing it from returning by some form of automatic mercury seal, and (3) those in which a constant, though slight, vacuum or tendency to vacuum is maintained, by connecting the system with the chimney and utilizing the "pull" of the draft.

These systems are now being rapidly installed in public buildings and dwellings, and no doubt will be found more satisfactory than steam for greenhouses. In addition to the advantages given above it is claimed for these systems that they are more economical of fuel than are either steam or hot water, that the circulation is better and surer, and also that there is no trouble arising in long runs from water of condensation.

Arrangement of Boilers.—In the common gravity system of steam heating the boilers must be below the level of all mains and coils. When they cannot be so located,

special devices to be described later must be employed to return the water of condensation. As with hot water, two or more boilers should be provided, rather than one large one, to allow for repairs in case of accident and for use in severe weather to avoid the necessity of forcing.

Steam Pumps and Traps.—As suggested in the preceding paragraph, it is sometimes impossible or inconvenient to place the boiler below the level of the heating coils. This is especially true in large establishments, requiring large boilers using large quantities of fuel. In order to return the water of condensation in such cases steam return traps and steam pumps are used. Their use is also necessary where a higher pressure is carried at the boiler than in the coils.

The return trap is a contrivance which is automatic in its action, and which overcomes the back pressure from the boiler by an ingenious method of equalizing the difference in pressure between the boiler and the coils. Being automatic in its action and requiring but little attention it has been quite generally used. Steam pumps, on the other hand, require considerable attention, though they

are less complicated than the return traps. A small, separate boiler is generally used to operate the pump, and the exhaust and surplus steam is turned into the general heating system after being reduced to low pressure. Gas and electric motors are also used to drive the pumps for returning the water of condensation.

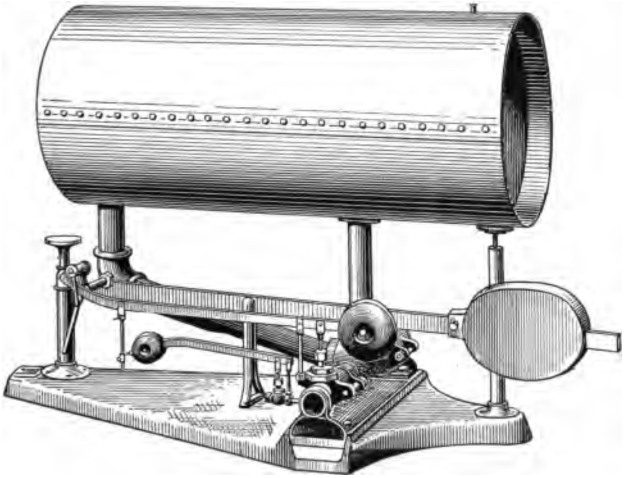

Fig. 102.—A type of steam return trap

CHAPTER XIII

BOILERS, FUELS AND FLUES

The terms boiler and heater as used in discussing greenhouse heating systems are synonymous. It is customary, however, to speak of a steam heating apparatus as a "boiler" and of a hot-water heating apparatus as a "heater," probably because in steam heating the water boils, while in hot-water heating it is not supposed to boil. It often occurs, however, that the same kind of heating apparatus is used in both steam and hot-water heating with no essential changes, except in the accessories. In this chapter the term boiler will be applied to both steam and hot-water heating devices.

The boilers used in greenhouse heating differ but little from those used in heating other buildings. In fact the same makes and styles of boilers are very frequently used for both purposes. Certain manufacturers have, however, made a thorough study of greenhouse heating and have developed boil-

ers with this particular end in view. In buying a boiler the safe plan is to purchase a style which has fully established itself on the market and which is made by a thoroughly reliable firm. Such boilers will have passed the experimental stage and repairs may be secured quickly and reasonably.

Essentials of a Boiler.—The function of the boiler is to extract the latent heat from the fuel and transfer it to the water or steam, which may be circulated when needed. The essentials are, a grate on which the fuel is burned and a watertight receptacle, so arranged as to present a large amount of surface (known as fire surface) to the fire or burning gases. The problem of the manufacturer is to so arrange and proportion the fire surface and the grate surface that the heat of the burning fuel may be most economically absorbed and distributed.

Grate Surface.—For best results the amount of grate surface should be large enough, so that the fire will not have to be forced. In small and medium-size boilers the rate of combustion should not exceed from five to seven pounds of coal per square foot of grate per hour. In larger boilers the rate of combustion of fuel may be as high as

from six to ten pounds per square foot per hour.

A pound of best coal has a heating value of about 14,000 B. T. U. per pound, of which only about 60 per cent. or 8,400 B. T. U. are utilized in heating water or producing steam. It is the usual practice to estimate that each pound of coal will impart about 8,000 B. T. U. to the heating medium, and that each square foot of grate surface will burn about six pounds of coal per hour. This gives 48,000 B. T. U. per square foot of grate surface per hour.

To find the approximate number of square feet of grate surface required to heat a given house, find the number of heat units required, by the method described in Chapter XI, and divide by 48,000.

In general, a square foot of grate surface is sufficient to supply 250 square feet of radiating surface.

Fire Surface.—Fire surface (sometimes known as heating surface or water surface) is of two kinds; direct and indirect. The direct fire surface is that immediately above or around the fire, against which the light of the burning fuel shines. Indirect fire surface is that which receives the heat from the

burning gases on their way to the chimney. Direct fire surface is three times as effective as indirect. It does not follow, however, that boilers having the greatest amount of direct fire surface are the most efficient, for there must be sufficient length of fire travel to consume the gases and enable them to give up the greater part of the heat of combustion to the water.

To be most effective the fire surface is so arranged that the heat will impinge at right angles against it. This is accomplished without serious interference with the draft, and without making the course of the water in the boiler so long and tortuous as to interfere with its rapid circulation. The proportion of fire surface to grate surface differs so widely in the different forms of boiler construction that no definite rule can be given. It may vary from 15 to 35 square feet to each square foot of grate area.

Types of Boilers.—Broadly speaking, there are three types of boilers, when classified as to their form of construction: (1) Boilers in which the water is spread out in thin sheets between layers of iron or steel and against which the heat strikes; (2) tubular

boilers in which the burning gases travel through tubes or flues which are surrounded by water; and (3) water-tube boilers in which the water is contained in tubes about which the burning gases circulate. Many

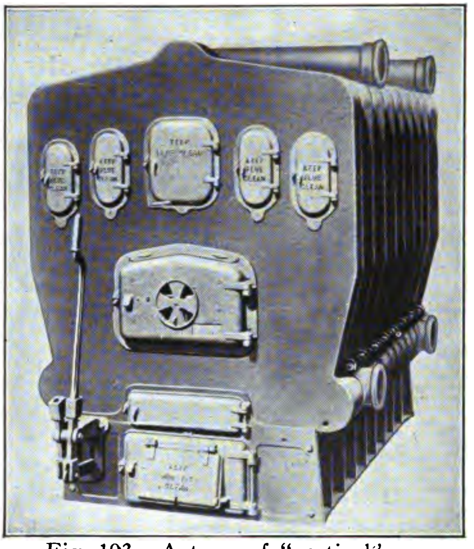

Fig. 103.—A type of "vertical" or "square" sectional boiler

manufacturers combine two, and sometimes all, of the above types in one boiler. The two latter types are more commonly used for power purposes than is the first, but for heating establishments of moderate size a modification of the first is widely used.

Cast and Wrought-Iron Boilers.—The cast-iron boiler has a size limit above which it is impracticable to go, though two or more may be joined in a series. It is also claimed that on account of the thickness of the walls

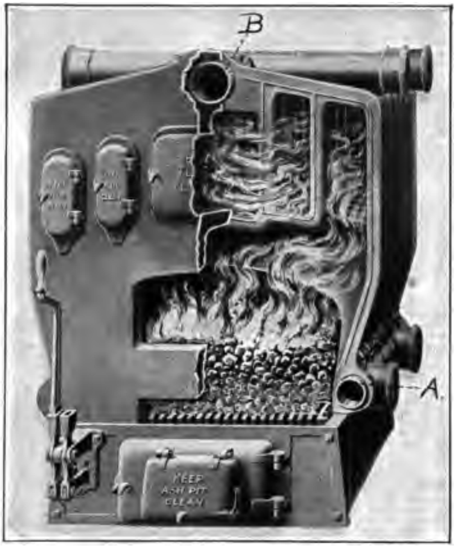

Fig. 104.—End view of "square" sectional boiler showing fire travel. A and B, push nipples for joining sections

it is less economical of fuel than are wrought-iron boilers, which have thinner walls. On the other hand, cast-iron boilers do not rust as badly as wrought-iron ones when not in use, and they have no flues to be burned out by the sulphurous gases resulting from the

use of the poorer grades of coal. But they do sometimes crack, and they have a disgusting way of doing it at the most inopportune moment.

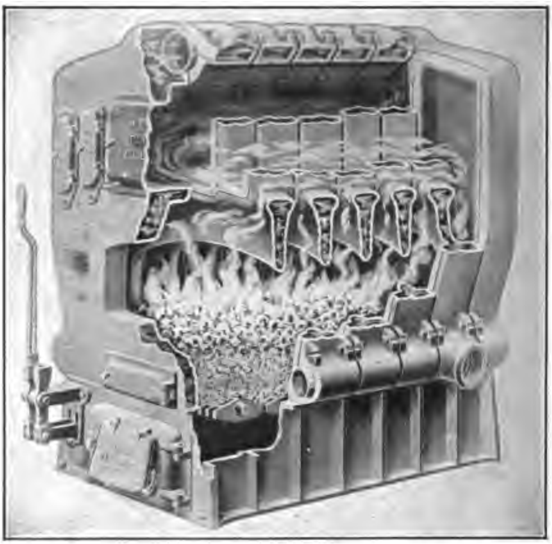

Fig. 105.—Side view of "square" sectional boiler showing fire travel

Where fuel is cheap and abundant, and especially in small ranges, or where the boiler is in a damp basement and likely to be neglected during the summer, cast-iron boilers are likely to give better satisfaction than wrought-iron. In large establishments of 100,000 feet or over, large wrought-iron tubu-

Fig. 106.—Battery of five cast-iron sectional boilers

lar or water-tube boilers are almost always used.

Styles of Cast-Iron Boilers.—There are three general types or styles of cast-iron boilers. The most popular is the "vertical" or "square" sectional boiler. The advantages claimed for these forms of boilers are: (1) They may be enlarged by adding extra sections; (2) a break or crack will usually be confined to one section; and (3) they may be made in large sizes because the individual castings are comparatively small and light. The sections are joined together by accurately ground push nipples or by screw nipples. Probably 80 per cent. of the cast-iron boilers now being placed in greenhouses of moderate size are of this general type.

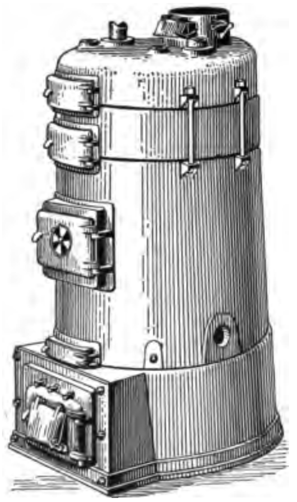

Fig. 107.—A type of "round" or "horizontal" sectional boiler

A second style of cast-iron boiler is known as "horizontal" or "round" sectional boiler. It gives good satisfaction in small

ranges but is not made in large sizes. In a third style there are no sections, but the boiler proper is cast in one piece. For this reason its size is limited. It is also open to the disadvantage that a crack will spoil the whole boiler. It is little used at present.

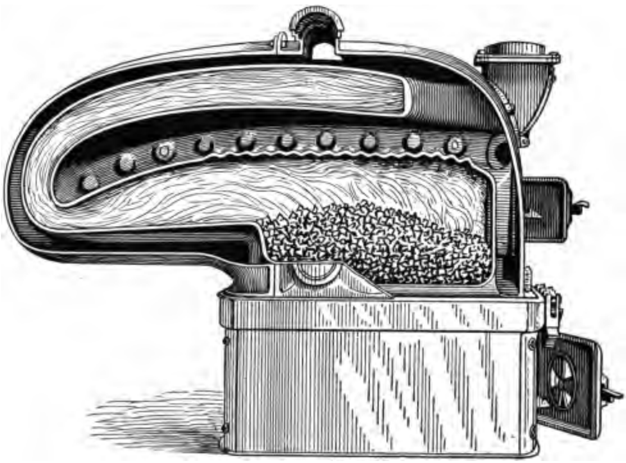

Fig. 108.—Corrugated fire box boiler. The boiler proper is of a single casting

Styles of Wrought-Iron Boilers.—Most wrought-iron boilers are either tubular or water-tube in construction, though the tubes or flues are sometimes connected with cast-iron headers. A new type of wrought-iron boiler is now being extensively advertised for greenhouse heating. It is claimed for this type that it steams more quickly than the

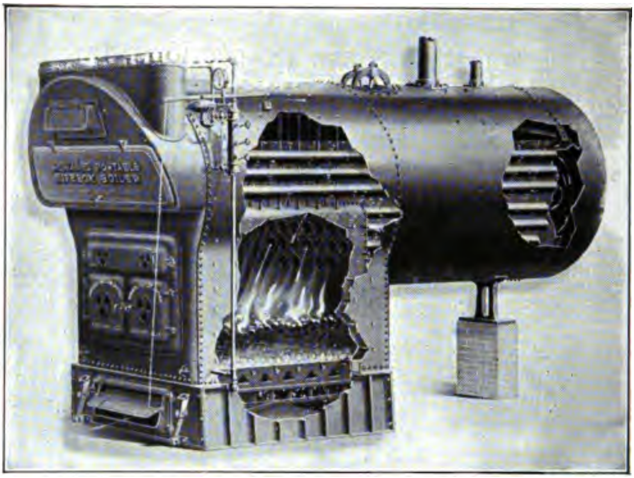

Fig. 109.—Type of tubular boiler much used in greenhouse heating

tubular boilers and that it is much more durable. As a rule users seem to be well satisfied with it.

Steam and Hot-water Boilers.—As usually constructed, low-pressure steam boilers differ but little in construction from hot water boilers. The essential difference is that in steam boilers provision is made for a steam chest or storage above the water line, while in hot-water boilers the space between the top of the tubes and the top of the boiler is so small that there is no room for an adequate steam storage. This is equivalent to saying

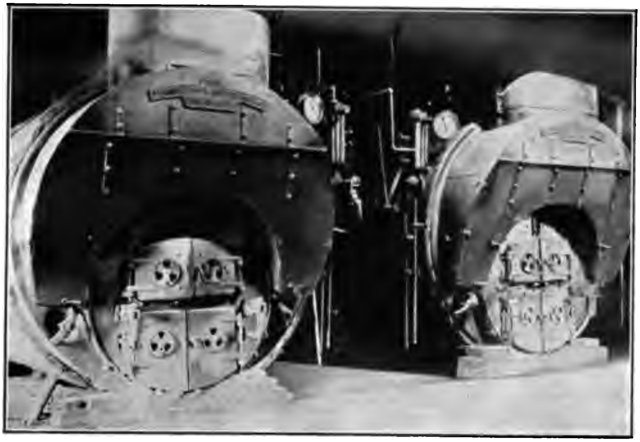

Fig. 110.—Battery of two marine type boilers used for greenhouse heating

that a steam boiler may be used for hot-water heating, but that a hot-water boiler is rarely satisfactory for steam heating. Large steam boilers are quite frequently used in hot-water heating when equipped with the necessary fittings which are described in a succeeding paragraph.

Boilers for Soft and Hard Coal.—Hard coal burns with a "short" flame, and much less fire travel is required to burn the gases than when soft coal, which burns with a "long" flame, is used. More flue way is also required for soft coal and the grates are more open. Most greenhouse boilers which are

designed for soft coal will burn hard coal equally well. If they are designed primarily for hard coal they will not burn soft coal efficiently. More grate surface is required for soft coal than for hard coal, because it is

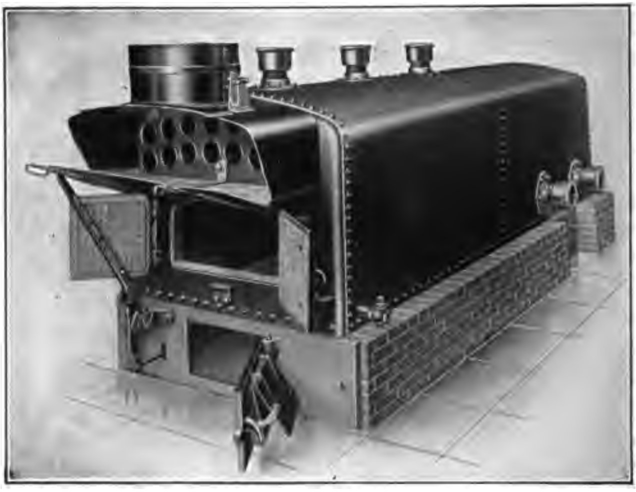

Fig. 111.—Wrought-iron boiler without flues

more bulky weight for weight. Most modern greenhouse boilers will burn either hard or soft coal, but a larger size will be required for soft coal than for anthracite.

Boiler Ratings.—An approximate idea of the size of boiler needed may be found by figuring the amount of grate surface by the method described on page 202. Boiler manu-

facturers, however, rate their boilers showing their capacity. Some give the number of square feet of glass that they will heat to a given temperature; others give the number

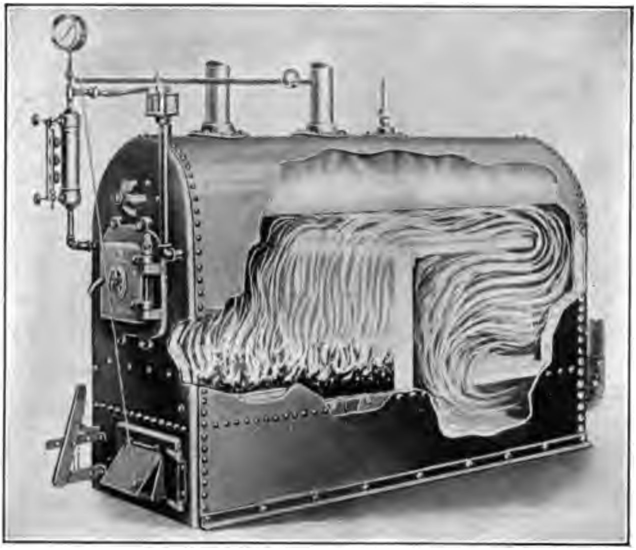

Fig. 112.—Sectional view of boiler shown in Fig. 111

of linear feet of radiating pipe of a given size which they will supply; and still others, especially the manufacturers of large tubular boilers, give the capacity of their boilers in terms of horse-power.

Since different manufacturers often question the correctness of the ratings of their

competitors, it is but fair that buyers should be recommended to exercise considerable caution. Probably most boilers will, under favorable conditions, develop the number of heat units for which they are rated, but for the sake of safety and to prevent the necessity of forcing, it is best to select boilers with ratings at least 20 per cent. in excess of the theoretical needs.

When boilers are rated according to the number of linear feet of radiating pipe they will supply, it is usually given in terms of either 3½-inch cast-iron pipe or in 2-inch wrought-iron pipe. The following table gives the length of pipes of other sizes equivalent to 1 linear foot of 2 and 3½-inch pipe.

1 ft. of 3½ in. C.I. pipe equals	3.04	ft. 1	in. W.I. pipe
1 ft. of 3½ in. C.I. pipe equals	2.41	ft. 1¼	in. W.I. pipe
1 ft. of 3½ in. C.I. pipe equals	2.10	ft. 1½	in. W.I. pipe
1 ft. of 3½ in. C.I. pipe equals	1.68	ft. 2	in. W.I. pipe
1 ft. of 3½ in. C.I. pipe equals	1.39	ft. 2½	in. W.I. pipe
1 ft. of 2 in. W.I. pipe equals	1.806	ft. 1	in. W.I. pipe
1 ft. of 2 in. W.I. pipe equals	1.431	ft. 1¼	in. W.I. pipe
1 ft. of 2 in. W.I. pipe equals	1.25	ft. 1½	in. W.I. pipe

Most boiler ratings are given for a minimum outside temperature of zero degrees, Fahrenheit. For localities subject to a temperature of 10 degrees below zero a boiler of 10 per cent. greater capacity should be se-

cured, and for localities subject to a temperature of 20 degrees below zero, a boiler of 20 per cent. greater capacity should be secured.

The term horse-power, as applied to boilers, represents the energy developed in evaporating 34.5 pounds of water per hour from a temperature of 212 degrees, or the development of 33,317 B. T. U. per hour. Roughly, a heating boiler will supply 100 square feet of radiation for each horse-power which it develops.

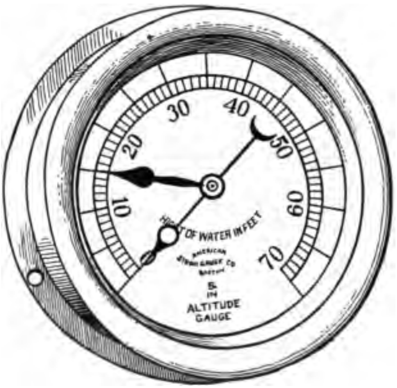

Fig. 113.—Altitude guage for hot water boiler

Boiler Accessories.—It has already been stated that a steam boiler may be used for hot-water heating by simply changing the fittings. When used for hot-water heating

the boiler is fitted with an altitude gauge, which shows the height of the water in the system; also with a thermometer to show the temperature of the water. A valve is provided for draining the boiler and, if desired, an automatic damper regulating device may be installed.

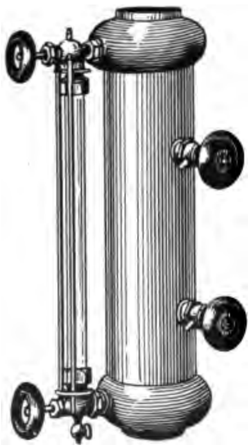

Fig. 114.—Water column and guage for steam boilers

When used for steam heating the boiler is only partially filled with water, and a water column and guage is necessary to indicate the height of the water. A steam guage is also necessary to indicate the pressure; and a safety valve to automatically relieve the pressure, if it becomes too great for safety. Steam boilers are usually equipped with automatic damper regulators. They are rather more efficient than the regulators used on hot-water boilers. A drainage valve is provided the same as for hot-water boilers. Many states require that all steam boilers be equipped with a fusible plug, which is simply a brass plug with a tin core, which

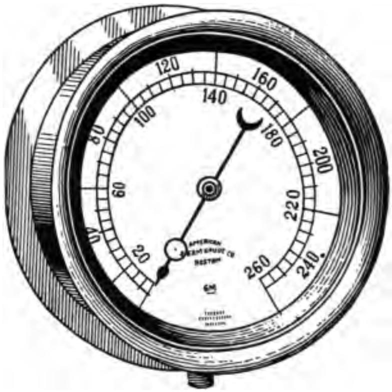

Fig. 115.—Steam guage

is screwed into a hole in the boiler near the bottom. If the water level falls below the plug the heat melts it out, thus making

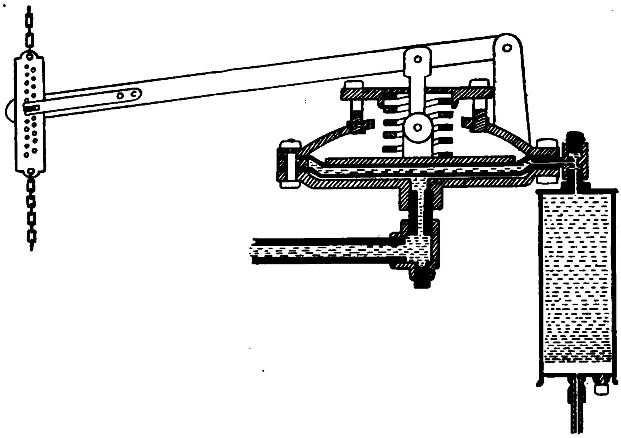

Fig. 116.—Diagram of automatic damper regulator. The steam pressure acts against a flexible diaphram which is connected with the dampers by means of a lever and chain

an opening and lessening the danger of an explosion.

The boiler and all pipes, except those in the greenhouse itself, should be insulated as much as possible to prevent loss of heat. The best known material for this purpose is asbestos. For coating boilers it may be had in a granular form, which is mixed with water and applied with a trowel or the bare hands. For covering pipes molded casings may be had to fit all sizes of pipe.

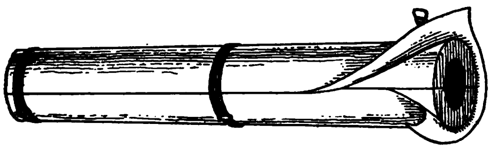

Fig. 117.—Asbestos pipe covering

FUELS

Coal is used almost universally for fuel in greenhouse heating, except in sections where natural gas or oil are cheap and abundant. Gas is an ideal fuel, but somewhat treacherous inasmuch as the pressure is likely to be lowest in the coldest weather. Care should be taken to see that there are no leaks, as it is very explosive, and it is also poisonous to vegetable as well as animal life.

Broadly speaking, coal is of two kinds,

anthracite or hard coal, and bituminous or soft coal. Hard coal burns with little smoke

Fig. 118.—Boiler equipped for using natural gas

and is much heavier than soft coal, although it may not develop as much heat per ton.

It is easier and cleaner to handle, and requires less attention in firing, but in most sections is more expensive.

Soft coals are of two general types; The free burning and the coking. The latter fuses together in burning and is somewhat more difficult to handle in the furnace than the free burning, though it is preferred by some firemen.

The heating value of a coal depends upon the percentage of total combustible matter contained, and upon the heating value per pound of the combustible portion. In some semi-bituminous coals the heating value runs as high as 15,750 B. T. U. per pound. The heating value of a few common types of coals as given by Kent are shown in the following table.

Kind of coal	B.T.U.	Kind of coal	B.T.U.
Anthracite		Cambria Co., Pa.	14450
Northern Coal field	13160	Somerset Co., Pa.	14200
East Middle field	13420	Cumberland, Md.	14400
West Middle field	12840	Pocahontas, Va.	15070
Southern field	13220	Brier Hill, O.	13010
		Scott Co., Tenn.	13700
Semi-bituminous		Big Muddy, Ill.	12420
Clearfield Co., Pa.	14950	Missouri	12230

Soft coal is more commonly used in greenhouses than is hard coal. This is especially

true in large establishments. The price varies with the quality, distance from the mines, etc.

The average cost for soft coal to 61 growers, living east of the Mississippi River, for the season of 1911-12, was $2.33 per ton. The average amount used for the season was 11.6 tons for each 1,000 square feet under glass.

Underfed Boilers.—The term "underfed" is applied to a method of stoking, in which the coal is fed from the bottom instead of the top of the furnace. It is claimed for this system that it insures a more perfect combustion and that cheaper grades of coal may be used. Boilers employing this principle have not come into very general use in greenhouse heating, probably because they will not handle successfully all grades of coal.

Self-stoking Boilers.—Stoking devices are practical only in large establishments using large boilers. There are several types, some of which work on practically the same principle as the underfed furnaces mentioned above, except that their action is automatic. In other forms the grate bars are arranged in the form of an endless chain, which is

moved slowly from the front to the rear of the fire-box by means of gearing. It is claimed for the self-stoking devices that they not only save labor, but that they are more economical in the use of fuel than is hand stoking.

Points to Consider.—The following points should be kept in mind in selecting a greenhouse heating boiler:

1. It should be of ample size—at least one size larger than is theoretically necessary.
2. The fire-box should be deep and spacious. This is especially true of boilers for small establishments where a regular fireman is not employed.
3. The combustion chamber (the chamber above the grate) should be large enough to insure thorough combustion of the gases.
4. The boiler should be so arranged that it may be easily cleaned, especially the flues and heating surfaces.
5. The grates should be heavy but easy to operate and easily removable, so that repairs may be made quickly.
6. The water travel should not be so circuitous as to prevent of rapid circulation.
7. There should be no packed joints. All

unions should be made with push or screw nipples.

8. Soft coal burners require a somewhat different construction than do hard coal burners. The kind of fuel to be burned should be clearly in mind when selecting a boiler.

9. The ash pit should be deep and commodious. Shallow ash pits are likely to become filled so that the draft is impaired and the grate bars ruined.

CHIMNEYS AND FLUES

A very essential part of the heating equipment is the chimney or flue. Its purpose is twofold: First, to create a draft in order to furnish air to promote combustion; and second, to carry off smoke and gas. The size and height of the chimney required depends on the size of the grate surface. Mere velocity does not necessarily indicate that the draft is sufficient; the chimney must be of sufficient size to carry the required quantity.

The velocity of the gas in the flue depends on the height of the flue and upon the temperature of the gas. The difference between the weight of the hot gases in the chimney, and a column of cold air of equal

size outside creates a flow upward in the chimney. This difference increases with the height of the chimney, and if the difference in temperature increases the velocity is more rapid. Locations high above sea level require higher chimneys than those near sea level, on account of the rarety of the atmo-

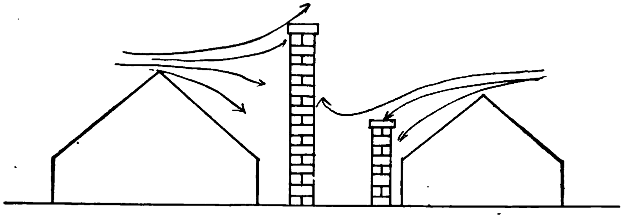

Fig. 119.—Chimneys should extend above the roofs of adjacent buildings

sphere. For example, at Denver, Col., (5,300 feet) the height should be about 20 per cent. greater than at sea level.

Chimneys should be vertical if possible and the inside should be smooth and free from all obstructions. They should also extend well above the roofs of adjacent buildings, particularly when there is danger of a "down draft." Round chimneys present less surface per cubic capacity than do square chimneys, and are thus more efficient. For the same reason square flues are better than oblong flues.

The following table shows the size and height of chimneys required by steam boilers. For hot-water boilers multiply the radiating surface by 1.5.

Sq. ft. st'm rad.	Height of chimney in feet							
	20	30	40	50	60	80	100	120
	Size of Chimney (dia. or 1 side sq.) in inches							
250	7.4	7.0	6.7	6.4	6.2	6.0	6.0	6,0
500	9.6	9.2	8.8	8.2	8.0	6.6	7.3	7.0
750	11.3	10.8	10.2	9.6	9.3	8.8	8.5	8.2
1000	12.8	12.0	11.4	10.8	10.5	10.0	9.5	9.2
1500	15.2	14.4	13.4	12.8	12.4	11.5	11.2	10.8
2000	17.2	16.8	15.2	14.5	14.0	13.2	12.6	12.1
3000	20.6	18.5	18.2	17.2	16.2	15.8	15.8	14.4
4000	23.6	22.2	20.8	19.6	19.0	17.8	17.0	16.3
5000	26.0	24.6	23.0	21.6	21.0	19.4	18.6	18.0
6000	28.4	26.8	25.0	23.4	22.8	21.2	20.2	19.5
7000	30.4	28.8	27.0	25.5	24.4	23.0	21.6	20.8
8000	32.4	30.6	28.6	26.8	26.0	24.2	23.4	22.2
9000	34.0	32.4	30.4	28.4	27.4	25.6	24.4	23.4
10000	27.0	34.0	32.0	34.0	28.6	27.0	25.4	24.6
15000	...	...	38.4	36.2	35.0	33.0	31.0	29.2
20000	...	...	43.0	42.0	41.0	37.0	35.0	34.0
30000	...	...	...	50.0	48.0	46.0	43.0	41.0

CHAPTER XIV

WATER SUPPLY AND IRRIGATION

An abundant supply of water at a reasonable cost is necessary for the successful operation of a commercial range of greenhouses. Figures compiled from the experience of several growers show that the consumption of water by a vegetable crop in a greenhouse during the bright, hot days of June and July may be as high as 280 gallons per day per 1000 square feet of crops. As the watering is done over a period of not more than three or four hours per day, it is necessary to make arrangements to supply the maximum amount needed during that length of time, rather than during the 24 hours of the day as is usually figured for domestic purposes.

When city water is available at a reasonable price it is doubtful if it will pay the small grower to go to the expense of providing a private supply. Sometimes, however, the conditions are such that a private

supply of water may be had at small expense from springs, ponds or streams. In larger establishments it may be cheaper to install a private system than to depend on city water. Often, also, the ranges are located outside the city limits where city water cannot be had. Data based on the reports of nearly 100 florists and vegetable growers show that the average cost per 1,000 gallons of city water is 18 cents, and that the average cost of the home supply, including cost of equipment, depreciation and maintenance, is 21 cents per 1,000 gallons.

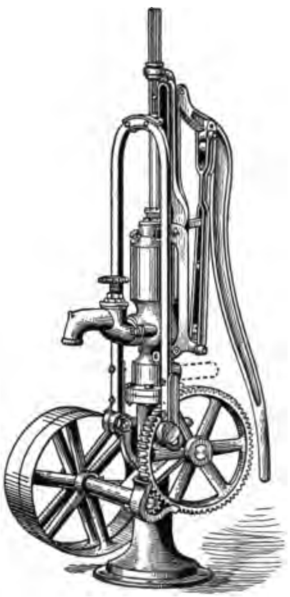

Fig. 120.—Pumping jack for applying power to a hand pump

Pumps.—For general purposes some of the many types of combination lift and force pumps now on the market are commonly used. Pumps of this type may be had which are directly geared to a gas or steam engine, or to an

electric motor. Usually, a hand pump of large size is used, and power is applied by means of a pumping jack.

A very efficient but somewhat delicate pumping device is the combined hot-air-engine and pump. These pumps give very good satisfaction where the water is reasonably close to the surface, or when it does not have to be pumped against too great a pressure. Improved types of large size are now available, and are very economical of fuel, but the engine is not as well adapted for general power purposes as are gas engines.

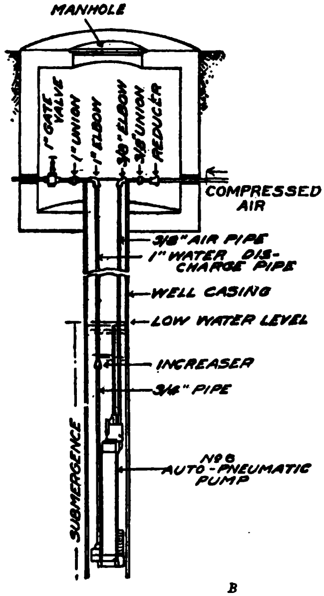

Fig. 121.—Diagram showing installation of an auto-pneumatic pump

A form of pump, which is becoming quite popular for domestic use is the auto-pneumatic pump. It is designed to be used in an open well or a cased well of large bore, as the pump proper is placed entirely be-

neath the water. It is operated by compressed air, hence an air pump and an air tank are required. Its chief advantage for domestic purposes lies in the fact that it starts automatically when the faucet is opened, thus giving a supply of cold water direct from the well. For greenhouse purposes this is a disadvantage, as the water may be too cold to use on the plants.

Pump cylinders should not be more than 20 feet above the surface of the water, as this is the limit of practical suction. When the water is more than 20 feet below the surface the pumping cylinders are lowered accordingly. In deep wells it is common to lower the pumping cylinders well into the water.

Capacity of Pumps.—The capacity of a pump depends upon the size of the cylinder and the length and rapidity of the strokes. The table on page 230 gives the discharge per stroke in gallons, of pumps having cylinders of various sizes. This, multiplied by the number of strokes per minute, will give the capacity per minute.

Power Required.—The power required to operate a given pump may be determined as follows: Multiply the number of gallons pumped per minute by 8.357 pounds (the

TABLE OF CAPACITY OF PUMPS

Diameter of cylinder in inches	Length of stroke in inches: 5	6	7	8	9	10	12	14	15	16
	Capacity per stroke in gallons									
2	.068	.082	.095	.109	.122	.136	.163	.190	.204	.218
2½	.106	.128	.149	.170	.191	.213	.255	.298	.319	.340
3	.153	.184	.214	.245	.275	.306	.367	.428	.459	.489
3½	.207	.249	.292	.333	.375	.417	.499	.583	.625	.666
4	.272	.326	.381	.435	.490	.544	.653	.762	.816	.870
4½	.344	.413	.482	.551	.619	.689	.826	.964	1.033	1.102
5	.425	.510	.595	.680	.765	.850	1.020	1.090	1.275	1.360
5½	.514	.617	.720	.823	.926	1.029	1.234	1.440	1.543	1.646
6	.612	.734	.857	.979	1.102	1.224	1.469	1.714	1.836	1.958

weight of a gallon of water). This will give the weight pumped per minute. Multiply this by the total lift in feet. This will give the number of foot-pounds of energy required per minute. Divide this by 33,000 (the number of foot-pounds in a horse-power) and the result will be the number of horse-power required. Pumping outfits are only about 50 per cent. efficient, so that the results obtained by the above are doubled in actual practice. On the average one horse-power will pump 30 gallons per minute to the height of 100 feet. In pumping water against pressure in a pneumatic tank, extra power will be required. Extra power will also be required when the water is pumped for any considerable distance, on account of the friction of the pipes. The frictional loss in feet of lift for each 100 feet of pipe of various sizes is shown in the following table.

Gallons	Size of Pipe					
per min.	¾ in.	1 in.	1¼ in.	1½ in.	2 in.	2½ in.
	Frictional Loss					
10	29.9	7.3	1.4	1.0	0.28	0.09
15	66.0	16.1	5.5	2.2	0.57	0.18
20	115.0	28.0	9.5	4.8	0.96	0.32
25	179.0	43.7	14.7	6.0	1.7	0.48
30	264.0	63.2	21.0	8.6	2.1	0.69
35	372.0	85.1	28.9	11.6	2.7	0.92
40	461.0	110.0	37.0	14.9	3.7	1.2

This loss by friction cannot be disregarded. Suppose, for example, it is desired to deliver 20 gallons per minute at a distance of 100 feet. By referring to the above table it will be seen that if a ¾-inch pipe were used, a loss equal to a head of 115 feet would be sustained, while if a 1½-inch pipe were used a loss of only 4.8 feet would be sustained. It is economy to use pipe of generous size.

Hydraulic Rams.—The hydraulic ram is a device which utilizes the force of water,

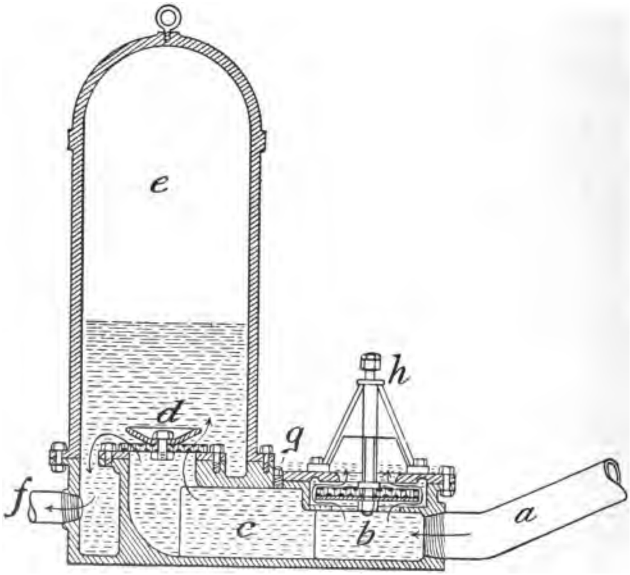

Fig. 122.—A simple type of hydraulic ram. a, intake pipe; f, delivery pipe

falling a short distance, to elevate a portion of the water to a greater height. It is wasteful of water, but when a never-failing stream of sufficient flow and fall is available it is one of the most economical and satisfactory of water-lifting machines.

Rams are somewhat difficult to install by a novice, because of the rather exacting con-

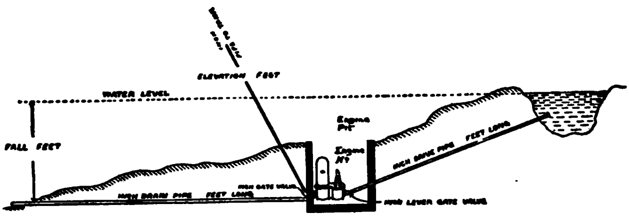

Fig. 123.—Plan for installing a hydraulic ram

ditions necessary to secure the most efficient service. When they are properly installed, however, they give little trouble, provided they are kept from freezing.

Capacity of Rams.—To find the capacity of a ram for any given conditions proceed as follows: Multiply the fall in feet by the quantity of water which may be supplied to the ram in gallons per minute, and divide the product by the height the water is to be raised. The result will be the number of gallons delivered per minute. The above

disregards loss by friction and assumes that a ram of the proper size is installed.

By use of the table on page 235 an estimate of the capacity of a ram for different conditions may be determined. The left-hand column indicates the number of feet of fall possible to secure, and the numbers at the top of the vertical columns indicate the height to which water is to be raised.

For example: Suppose we have a stream with a flow of 100 gallons per minute; that there is an available fall of 10 feet, and that it is desired to raise the water 40 feet. The factor in this case (252) will be found in the column headed by 40 and opposite the number 10 under power head. Multiplying 252 by 100, we have 25,200, the number of gallons that may be delivered per day by a ram of the correct size.

In ordering a hydraulic ram the following information should be given:

1. Flow of water in gallons per minute.
2. Vertical fall in feet.
3. Distance in which fall is obtained.
4. Vertical height above ram the water is to be raised.
5. Distance water is to be forced.
6. Number of gallons required per day.

ESTIMATED CAPACITY OF RAM FOR DIFFERENT CONDITIONS

Power head in feet	Pumping head in feet 10	15	20	30	40	50	60	70	80	90	100
5	540	345	240	160	120	96	80	69	60	53	43
6	...	432	302	192	144	115	96	82	72	64	57
7	...	505	378	235	168	134	112	96	84	75	67
8	...	...	432	270	192	154	128	110	96	86	77
9	...	...	485	300	216	173	144	124	108	96	86
10	...	...	540	360	252	192	160	137	120	107	96
12	...	...	...	430	301	230	192	165	144	128	115
14	...	...	...	505	353	270	224	192	168	150	135
16	...	...	...	...	432	323	257	220	192	171	154
18	...	...	...	...	486	390	303	247	216	192	173
20	...	...	...	...	540	430	336	288	240	214	192
22	...	...	...	...	...	475	370	303	264	235	212
24	...	...	...	...	...	520	405	346	288	256	230
26	...	...	...	...	...	...	470	375	328	278	250
28	...	...	...	...	...	...	505	430	354	300	269
30	...	...	...	...	...	...	540	465	405	336	288

To use: Multiply the factor opposite power head and under pumping head by the number of gallons of water available per minute. The product will be the number of gallons delivered per day. (See page 234.)

Double-acting rams which will utilize the water from a creek or river as power and pump water from a spring or shallow well may be had, but they are somewhat more complicated.

Windmills for Pumping.—The chief objection to the windmill for pumping is its lack of dependability. Where the wind is fairly constant, or when a large storage capacity may be had cheaply, windmills are the cheapest source of power. On the average the windmills used for pumping develop about three-fourths horse-power. The geared steel wheel mills are more efficient and will run in lighter winds than will the wood wheel mills.

Storage Tanks.—Storage tanks are necessary with most water systems, to insure a constant supply and to furnish pressure. They fall naturally under two heads: (1) Open tanks in which pressure is obtained by gravity; (2) closed tanks, usually pneumatic tanks, containing air into which water is forced, the compressed air in this case furnishing the desired pressure.

In placing tanks in the attic, or other elevated positions, it is well to keep in mind the

weight of water and to see that the supports are amply strong. For example, a 10-barrel tank of water will weigh, in addition to the tank itself, more than one and a quarter tons.

The pressure to be obtained from elevated tanks depends upon their elevation, each additional foot giving a pressure of about 0.433 pounds per square inch. The following table shows the pressure (disregarding friction) to be obtained at various heights.

Height in feet	Pressure per sq. inch
10	4.33 pounds
20	8.66 "
30	12.99 "
40	17.32 "
50	21.65 "
60	25.98 "
70	30.31 "
80	34.64 "
90	38.97 "

The advantage of the pneumatic tank lies in the fact that it may be placed in any out-of-the-way place in the basement, or it may be buried in the ground below the frost line. There is little danger in its use if it is provided with a pressure gauge and safety valve.

Capacity of Storage Tanks.—The capacity of storage tanks is not difficult to arrive at by simple mathematics, unless they are

of unusual shapes. For convenience, tables are given below showing the capacity of round and square tanks of standard sizes. When pneumatic tanks are used, about a third of their capacity is occupied by the compressed air.

TABLE SHOWING CAPACITY OF ROUND STORAGE TANKS

Diameter Feet	Height Feet	Capacity Gallons	Diameter Feet	Height Feet	Capacity Gallons
4	4	378	5	6	735
4	5	470	5½	8	1400
4	6	567	6	2	423
4	8	756	6	2½	528
5	3	440	6	3	635
5	4	588	6	4	845
5	5	735	6	5	1056

TABLE SHOWING CAPACITY OF RECTANGULAR TANKS

Width Feet	Height Feet	Length Feet	Capacity Gallons
2½	2½	8	378
3	2	8	360
3	2	10	448
3	½	8	448
3	2½	10	565
3	3	10	673
4	2	8	478
4	2	10	598
4	2½	8	598
4	2½	10	748
4	3	8	718

Fig. 124.—Overhead irrigation. (Courtesy Skinner Irrigation Co.)

IRRIGATION

There are two general methods of watering greenhouse crops aside from hand watering. One is by an overhead sprinkling system; the other is by an underground or sub-irrigating system. Of these the overhead system is by far the more popular. A census of a large number of growers of greenhouse vegetables shows that practically 75 per cent. use some form of overhead irrigation, while only two out of the whole number consulted were using sub-irrigation.

Fig. 125 — A type of nozzle used in overhead irrigation

Practically the only system of overhead irrigation used in greenhouses is one in which pipes, fitted with nozzles which throw a rain-like spray, are run lengthwise of the house and so arranged that they may be rotated to throw the spray on both sides of the pipe line. The original system is known as the Skinner system, but there are others now on the market. Pipe lines for this system should be about 16 feet apart and as far from the foliage as possible. The nozzles should be 3 feet apart. This system will operate

satisfactorily on a water pressure of from 10 to 30 pounds.

When constructing benches for sub-irrigation, the essentials are a water-tight bottom, usually of cement, to prevent the water from leaking through, and perforated pipes or tiles for distributing it along the bench. This system has been tried out extensively with varying results by the Ohio experiment station.

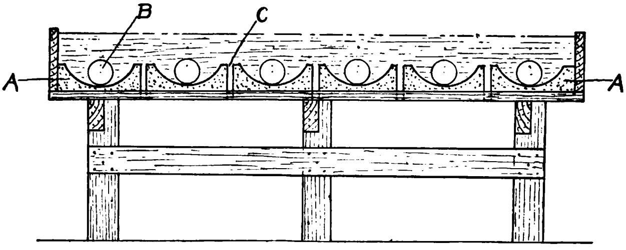

Fig. 126.—Greenhouse bench arranged for sub-irrigation. A, cement troughs on bottom of bench; B, drain tile or perforated pipes for supplying water; C, drainage spaces between troughs.

CHAPTER XV

CONCRETE CONSTRUCTION

Concrete is a combination of Portland cement, sand, crushed stone or gravel and water, thoroughly mixed and then allowed to set or harden.

Portland cement, or cement, as it is now commonly known, is manufactured by burning and grinding together limestone and clay, or shale, in certain proportions. It derives its name, Portland cement, from its resemblance to Portland stone. It is also sometimes known as hydraulic cement, or building cement.

Concrete has wellnigh revolutionized building practice in the last 25 years, but in no case has it displaced masonry to a greater extent than in greenhouse construction. Formerly, the walls of a greenhouse were a source of much trouble, because of their rapid deterioration, but it was soon found that when concrete was used they be-

came the most stable part of the structure. Concrete is practically the only material now used for the foundations and walls of commercial greenhouses, and to a great extent it has displaced masonry for private greenhouses.

At present cement is almost universally handled and shipped in cloth or paper sacks holding 95 pounds. It is often spoken of, and is sometimes quoted by the barrel, this now meaning simply four sacks, or 380 pounds. As a rule, the most satisfactory form in which to buy cement is in cloth sacks. The sacks may be returned when empty, and if not torn a credit of about 10 cents each may be realized.

Sand.—Sand, to give the most satisfactory results, should be free from clay or organic matter, and rather coarse. Very fine sand will require a greater proportion of cement and as a consequence the concrete will be more expensive. In a small way, sand that contains some organic material may be washed and thus made satisfactory, but it is an expensive process.

Stone.—Either crushed stone or gravel may be used in making concrete, the only difference being that the crushed stone usually has a cleaner surface and the cement will cling to it more tightly. When gravel is used it should be free from clay, and the individual stones should be clean and bright and not covered with a layer of clay or soil.

The size of the stones may range from a fourth to two and a half inches in diameter, the size depending on the use to which the concrete is put. The best results are obtained when the sizes vary regularly from small to large, in order that they may settle well together when the concrete is poured.

Run of the Bank gravel is sometimes used. This is economical only when it contains sand and gravel in the correct proportions, as explained in a succeeding paragraph.

Crushed Stone may also contain very fine, medium and coarse stone in the correct proportions, so that no sand need be added, but such a condition is rare, unless the stone is ground and furnished for this special purpose.

Proportions of Materials.—Theoretically, the ideal concrete is a mixture in which all the spaces between the stones or gravel are

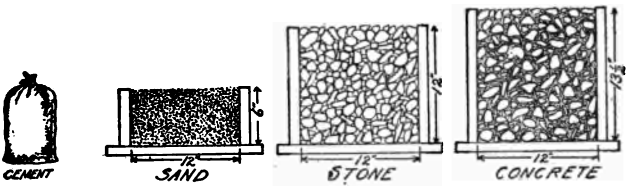

Fig. 127.—Proportions of cement, sand and stone required to form concrete

filled with sand, and all the spaces between the grains of sand are filled with cement. From this it will be seen that the total bulk of concrete would not be greatly in excess of the bulk of stone or gravel, as the sand and cement would go to fill the vacant spaces (voids). This is really true except that, as usually proportioned, a slight excess of cement is allowed. This is wise in order to insure that there shall be a film of cement about each stone and grain of sand, so they may be all bound together in a solid mass.

The common formula for most concrete work is known as the 1:2:4 mixture. In this there are: 1 part by measure of cement, 2 parts of sand, and 4 parts of stone or gravel.

This is the formula commonly used for walls above ground and for bridges and similar work. For sidewalks, floors, etc., which are supported on a firm foundation and are not subjected to heavy strain, a weaker mixture of 1 part of cement, 2¼ parts of sand and 5 parts of stone or gravel, is sometimes used.

For plastering the outside of walls and for similar purposes a mixture of cement and sand alone in the proportion of 1 to 1 is used, as it is easily worked and leaves a smooth surface.

Mixing.—For small jobs concrete is usually mixed by hand. The essentials are: (1) A tight platform or mixing board of sufficient size; (2) a convenient measuring box; (3) suitable shovels; and (4) a supply of water. Quite commonly the sand and gravel is measured in the wheelbarrows in which it is hauled, a little experience, secured by carefully measuring the amount for a few times, being all that is necessary to insure sufficiently accurate measuring. The barrow loads are checked up from time to time, however, to see that they are not over-running or falling short.

It is convenient to mix in batches requiring even bags of cement. For example, a two bag batch would mean two bags of cement, a quantity of sand equal to 4 bags (3¾ cubic feet) and 8 bags (7¼ cubic feet) of stone or gravel. They are mixed together thoroughly, shoveling over several times before adding the water.

Amount of Water.—The quantity of water used has but little effect on the resulting concrete, the amount depending rather on the consistency at which the concrete can best be handled for the special purpose for which it is to be used. The dryer the mixture the more quickly it will set.

For thin walls, or where the form contains many indentations, the mixture should be thin enough to run off the shovel quickly in handling.

For walls of medium thickness (6 to 12 inches) or for floors, walks, etc., it should be jelly-like in consistency, so that it will pile up somewhat on the shovel, but will slowly settle and run off the sides.

For foundations, underground, where it is important that the mixture set as quickly as

possible, it may be mixed so dry that it will handle like damp earth. Care must be taken in making this "dry mixture" that every part is moistened.

Estimating Materials.—The quantity of cement, sand and gravel necessary for a given piece of work may be found by multiplying the number of cubic feet by the percentage of cement, sand and gravel in a cubic foot of the mixture to be used. For convenience these proportions are given in tabular form in terms of barrels of cement and cubic yards of sand and gravel.

TABLE SHOWING PROPORTIONATE QUANTITIES OF CEMENT, SAND AND GRAVEL IN A CUBIC FOOT OF CONCRETE

Mixture	Cement barrel	Sand cubic yard	Stone or gravel cubic yard
1:2 :4	0.058	0.0163	0.0326
1:2½:5	0.048	0.0176	0.0352

To use, multiply the number of cubic feet of concrete required by the factor shown in the table. The result will be the quantity of the material required.

For example, 1000 cubic feet of 1:2:4 concrete would require

1000 x 0.058 or 58 barrels of cement
1000 x 0.163 or 16.3 cubic yards sand
1000 x 0.0326 or 32.6 cubic yards gravel

In estimating for cement mortar, figure 1 cubic foot to each 15 square feet of surface to be covered. Each cubic foot of 1:1 sand and cement mortar requires 0.1856 barrels of cement and 0.0263 cubic yards of sand.

Forms.—As concrete is soft when mixed, it is necessary to have some kind of a form or mold to hold it in the desired form and position until it hardens. For foundations, for such structures as greenhouses, a trench is usually dug 12 or 14 inches wide, and deep enough so that the bottom will be below the frost line. If the soil is firm enough to hold its place no form will be needed, but the concrete may be poured directly into the excavation, tamped and allowed to harden.

For that part of the wall which is above ground, however, a form is needed. It is important that this form be vertical, that it be straight, and that it be smooth in the inside so that the resulting wall will be agreeable to the eye. The making of the forms is important. They should be built by an experienced carpenter.

Any kind of lumber which is free from knot holes and has been surfaced to an even thickness will answer for forms. If the wall is a high one it may be necessary to tie the sides of the form together with wire. The wires remain in the concrete when the form is removed, but may be cut off flush with the surface, and if the wall is plastered they will not be noticed.

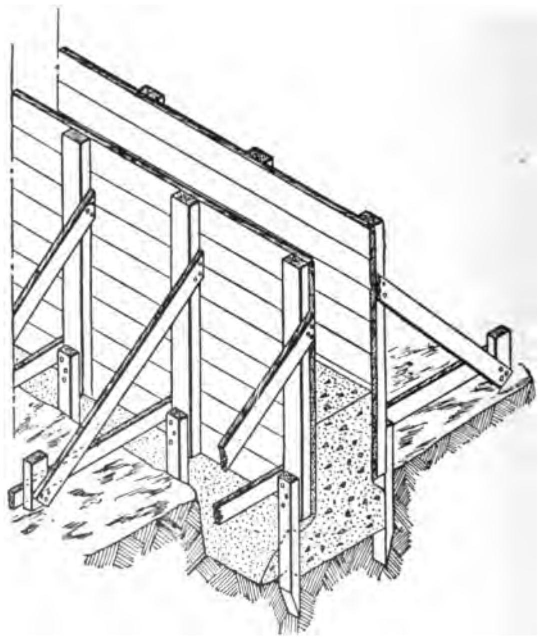

Fig. 128.—Form for a concrete wall

Filling the Forms.—In filling the form the concrete is placed in layers about 6 inches deep and tamped lightly until water shows on the surface. This will insure its settling together closely. If the wall is not to be plastered and a smooth surface is required, a spade or paddle is run down all along between the concrete and the sides of the form when the concrete is poured. This will force the larger stones toward the center of the wall and allow the smaller stones and sand to fill in next to the form, thus making a smooth surface.

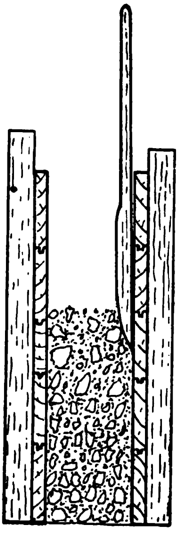
Fig. 129.—Method of facing a concrete wall

Reinforcing. — Concrete will withstand enormous crushing loads, but in walls where there is a considerable side strain, it should be reinforced with iron or steel. The best materials for this purpose are iron or steel rods. If they are twisted or roughened in some manner, so that the concrete will adhere to them tightly, their efficiency will be greatly increased. They are put in the

forms, usually vertically, about midway between the sides and 2 or 3 feet apart before the concrete is poured.

When an extra strong wall is required rods may be laid horizontally on the top of every layer or every second layer as the concrete is placed and tamped down into the soft mixture. When the walls extend only 3 or 4 feet above the surface and are at least 8 inches thick as is commonly the case in greenhouses, little if any reinforcement is needed.

Walks and Floors.—Concrete walks are now very commonly used in commercial as well as private greenhouses, and the boiler and service rooms are usually floored with concrete. As the walks are not usually subject to as hard usage as those laid out-of-doors, or to the action of frosts, it is not necessary to make them quite as thick, but in other respects they differ but little from the concrete sidewalks now so common.

The common method of building walks in a greenhouse is to make an excavation a few inches deep and as wide as the walk is to be and fill it with broken stone, pieces of brick, etc., to make a foundation. On top of this, two pieces of straight 2 x 4-inch lumber are placed on edge, level with each other and

with their inside edges spaced just as far apart as the walk is to be wide. They are then fastened by driving stakes on the out-side and nailing. The concrete is then poured into this form to within about an inch of the top and tamped firmly. A top coat, usually of finer material, is then placed on top of the first layer before it is set, and struck off by running a straight edge along

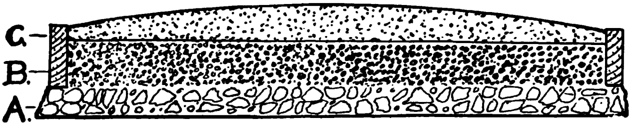

Fig. 130.—Structure of a concrete walk. a, foundation; b, coarse concrete; c, finish coat of fine concrete

the tops of the side pieces. This is then troweled by hand to give a smooth and slightly curving surface.

To allow for expansion and contraction, the walk should be cut into blocks before it sets. This may be done by putting in pieces of thin sheet-iron at regular intervals to be removed when the concrete has partially hardened. Sometimes the walk is cut through with a spade while still soft, at regular intervals and fine, dry sand placed between the blocks so made. This is usually quite satisfactory and by careful troweling

a very neat walk may be made in this way.

For the lower layer, when there is a firm foundation, a 1:2½:5 mixture will be satisfactory. The top layer should be of a 1:2:4 mixture or, when an especially smooth surface is required, of a 1:2 mixture, that is, one part of cement and two parts of sand.

Floors are laid practically the same as walks, except that they are usually troweled level instead of curving. The work is begun at one side of the floor, and as soon as one section has been laid and has had time to set, the side boards are taken up and put down for the next section. Floors should seldom or never be laid in a solid mass.

Waterproofing.—Much trouble is often experienced in underground boiler rooms from water. The best protection is to lay a row of tile completely around the outside of the foundation, at the bottom, and connect it with the sewer or drain. If the bottom of the cellar is springy it may be necessary to lay the floor in a solid piece and in two layers. After the first layer has set and become dry, or nearly so, a thick coating of hot tar may be applied, allowing it to extend for a few inches up the side walls. When this has hardened put on another coat

of rich concrete, troweling it up the sides as far as the tar has been placed. When an absolutely watertight job is required it may be necessary to coat the entire outside surface of the walls with tar and then bank up with earth.

Several so-called waterproofing materials designed to be placed in the concrete when

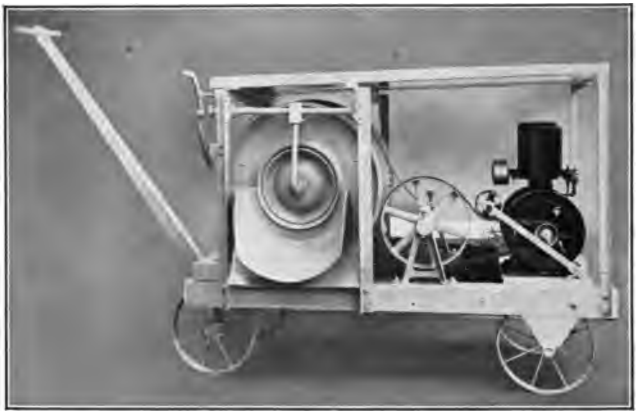

Fig. 131.—A small power machine for mixing concrete

it is mixed are on the market, but as a rule they are not fully satisfactory.

Concrete Blocks.—Blocks made of concrete in special molds or forms are sometimes employed for walls. They are usually hollow and for that reason make a warmer and somewhat dryer wall than does solid, poured

concrete. Experience shows that as a rule they are less durable than solid walls, but when the cost of material and labor for making forms is considered they may be more economical. They are often made with an ornamental face resembling broken stone, and make a somewhat more pleasing appearance than a plain wall.

Cost of Concrete.—So many factors enter into the cost of concrete that no reliable general estimate can be given. The price of cement is now fairly constant and uniform. The cost of sand and gravel or crushed stone, on the other hand, differs widely. In some places it may be had on the premises, in others it may have to be transported for several miles. Other factors entering into the cost are labor and the size of the operation. Where the quantity of work will justify the use of a power mixing machine, the cost is usually less than when the mixing is done by expensive hand labor, although the cost for labor may often be greatly reduced by carefully planning the work.

In general the contract prices for walls on comparatively small jobs range from 7 to 20 cents per cubic foot, and for walks and floors from 4 to 15 cents per square foot.

CHAPTER XVI

PLANS AND ESTIMATES

The cost of any kind of a building must necessarily vary with the cost of building material and the price of labor. This is especially true with greenhouses, since the materials used (glass especially) are subject to extreme fluctuations in price. In the preceding chapters it has been the aim to give all the data necessary for estimating the amount of material required for any given house, but no attempt has been made to state definite prices.

Little can be added in this chapter to what has already been given, and it would be useless repetition to collect the data into one chapter, as it may be easily found by referring to the index. An effort has been made, however, to make some suggestions as to the probable cost of different types of houses under varying conditions.

Basis of Estimates.—Since the economic value of a greenhouse depends on the area of

surface covered (bench space) it is common to estimate costs in terms of square feet of surface covered. In an investigation among a large number of growers (all types of houses) the author found that the first cost averaged not far from 45 cents per square foot of surface under glass. This included cost of heating system, but did not include cost of service buildings.

The cheapest plant on which data was secured was a range of four all wood frame houses, 16 x 50 feet, which had been in service for nine years and which was built at a cost of $525, or about 22 cents per square foot. In this case a second-hand boiler was used. Several larger ranges heated by steam from a central heating plant have been built at a cost of between 30 and 40 cents per square foot, though at a time when material was low in price. Data on modern semi-iron construction, when the labor was performed for the most part by the owner and his help, show a cost of between 50 and 60 cents per square foot, and all iron construction between 60 and 75 cents per square foot. All these, of course, were standard commercial houses. Private and public conserva-

tories and ornamental houses often cost two and three times as much.

Detailed Estimates.—Detailed estimates necessarily differ with the grade of material used. The following is a detailed estimate at current prices of the material needed for and the cost of a sem-iron frame house 30 x 90 feet, not including labor of erecting.

850 cubic feet concrete (wall and piers)—
  50 barrels cement
  14 cubic yards sand
  28 cubic yards gravel $100

PIPE

Side Posts—
  32 pieces 2-inch pipe, 5 feet 6 inches
Purlins—
  360 feet 1¼ inch
Purlin Supports—
  24 pieces 1½-inch pipe, 8 feet 3 inches
  24 pieces 1½-inch pipe, 11 feet
Cross Ties—
  24 pieces 1¼-inch pipe, 5 feet
  24 pieces 1¼-inch pipe, 8 feet 6 inches
Pipe and fittings for water lines, 100 feet ¾ inches $75

PIPE FITTINGS

32 Gutter brackets
120 Clamp fittings
48 Foot pieces
140 Purlin clasps $30

MILL WORK

240 feet sill
180 feet eave plate

90	feet ridge	
180	feet drip gutter	
4	pieces gable rafter, 18 feet long	
268	pieces sash bars, 18 feet long	
4	pieces corner bars, 4 feet long	
268	pieces glazing bars, 4 feet long	
180	feet sash header	
330	feet glazing bar	
100	feet 2x4 for door casing and gable bracing	
1	door	
	Ventilator sash with stops	$200

GLAZING

86	boxes glass (16x24)	
500	pounds putty	
8000	glazing points	$250
	Ventilating apparatus	$25
	Nails and other hardware	$25
	Paint	$50
	Freight	$15
	Miscellaneous items	$25

HEATING

Boiler (hot water)	
Pipe and fittings	
Brick for flue	$550
Total	$1345

This house covers approximately 2700 square feet of surface, which at a cost of $1,345 gives a cost per square foot of 49.81 cents for materials, but not including labor.

Figures on a similar house 31 x 100 feet submitted by a well-known manufacturer of greenhouse materials are given below:

WOODWORK

200 feet gutter with drip	
100 feet ridge	
228 feet glass sill	
175 feet gable end bars	
4 pieces gable rafters, 18 feet long	
144 pieces sash bars, 18 feet long	
12 ventilators	
12 pieces ventilator sash cap	
60 headers	
144 side bars	
4 corner bars	
1 door	$177.01
Ventilating machine complete	$26.40
Hinges for ventilators	3.60
Trussing material	5.20
Hardware for doors	.63
PIPE, POSTS AND FITTINGS (walls)	
40 pieces 2-inch, 5 feet long	
40 pieces post tops	$27.20
Nails	2.50
10 pounds glazing paints	1.30
400 pounds putty	14.00
Paint	32.00
Glass, 4600 square feet	260.00
Purlins, fittings and purlin supports	61.75
Gable bracing material	2.50
Heating plant complete	703.33
Total	$1317.42

The latter estimate does not include cost of materials for walls, but in other ways is complete. The cost per square foot of surface covered is 43.9 cents not including wall and cost of erection.

For an all wood frame house the cost of material will probably be from 15 to 25 per cent. less than the above and the cost of erection from 10 to 20 per cent. less.

For an all metal frame house the cost for materials will range from 25 to 40 per cent. greater than for the semi-iron construction, but the cost of erection will be less.

Information Required for Estimates.—In writing for estimates the following information should be given:

1. Type of house (semi-iron, all metal, etc.).
2. Kind of roof (even span, three quarter span, etc.).
3. Length and width (if range, send sketch showing arrangement).
4. Height to eaves.
5. Pitch of roof or height to ridge.
6. Size of glass preferred.
7. Kind of heat (hot water, steam, vapor).
8. Temperature to be maintained.
9. Coldest outside temperature expected.
10. Kind of fuel (hard or soft coal).

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